

PHOTOGRAPHIC

,
FACTS AND FORMULAS

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By

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Revised and largely rewritten by

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PREFACE

This book follows a long line of distinguished predecessors which have been the working companions of a full generation of photographers. The work was first undertaken by H. Snowden Ward and carried on in successive editions by Arthur D. Godbold and Prof. E. J. Wall, culminating in the edition of 1924. The present volume is brought out in response to a continuous demand for a work of this sort that will give in convenient form the essential facts and formulas constantly used in photography. The years intervening since the previous edition have seen photography moving so rapidly that the book had to be practically rewritten to bring it up to date, although many of the old formulas that have proved their permanent worth have been retained, along with the host of new ones necessary to keep up with the procession.

The book is intended as a working guide to practical photographers, giving them in easily accessible form, plain working directions and formulas for all the most commonly used photographic processes. It makes no pretence of imparting scientific information, which is readily available in many standard works dealing with that phase of the subject. Descriptive matter has been introduced only so far as it seemed necessary to give the reader a comprehensive idea of the processes for which directions and formulas are furnished, so that the formulas could be chosen and used more intelligently. It is also hoped that the descriptive matter, by increasing the reader's knowledge of photographic terms, will enable him to better understand his general photographic reading.

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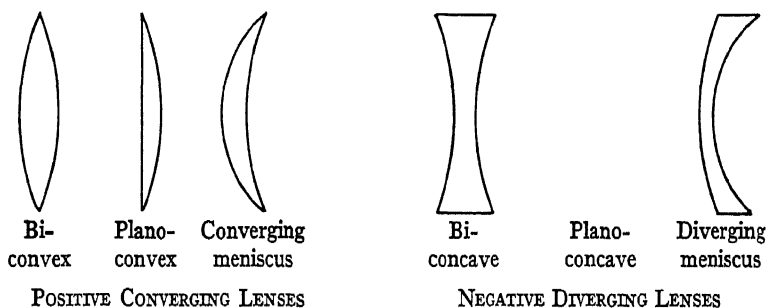
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CHAPTER I

OPTICS

LENSES. — Photographic lenses are masses of glass, or other transparent material, of such shape that they converge the rays of light reflected from an object and form an image of it. A *virtual* image is an upright, magnified image visible only by an observer looking through the lens, as with field glasses or microscopes. An *optical* or *real* image is one that can be produced upon a mat screen. It is always inverted, and is the one that is used in making photographic negatives. When two or more lenses are combined in a single mount and worked as a unit, the combination is properly called an *objective*, but in common usage the whole system is called a lens. The *optical axis* of a lens is an imaginary line drawn perpendicularly through the center of the lens surfaces. When lenses are used in combination, their optical axes must coincide. The *secondary axis*, which is used for optical calculations, is an imaginary line formed by the interrupted path of a ray of light when passing through a lens.

Single lenses, or the elements of compound lenses, that are thicker at the center than at the edges, cause light rays to converge upon the optical axis, and are called *convergent* or *positive* lenses. Lenses that are thicker at the edges than at the center, cause light rays to diverge from the axis, and are called *divergent* or *negative* lenses. In the illustration of the six most common types of simple lenses, the first three are convergent and the last three divergent.



For his first photographs, Daguerre used a single lens, partially corrected for achromatism, which worked at $f:14$ and covered a circle the diameter of which was only half the focal length. In 1840, Voigtlander brought out his famous portrait lens designed by Joseph Petzval, a mathematician of Vienna, which was the first lens to be calculated by a mathematician for photographic purposes. His aim was to make a lens with as many optical corrections as pos-

sible, while working at a large aperture to avoid the interminable length of exposure necessary with existing lenses. He succeeded in making a lens that worked at $f:6$, which was ultimately reduced to $f:3.4$, but only at the expense of a very narrow angle of field (about 20° to 25°). This was quite sufficient for a bust portrait, and the lens, with some modifications, had a wide popularity which persisted long after the advent of lenses of better correction. Petzval's formula was the basis for practically all subsequent portrait lenses which were not anastigmatic. The next great advance in photographic lenses was in 1866 when Steinheil and Dallmeyer each independently discovered and brought out doublets of the rapid rectilinear type, with a much wider angle of view, working at about $f:8$, and the usefulness of this type of lens was greatly increased when its two parts were corrected so that they could be used separately, each of the components becoming an individual lens of greater focal length, but lesser aperture. Although Petzval in 1843 had discovered the principles for the correction of astigmatism, it was not until 1890 that Paul Rudolph, taking advantage of the newly discovered Jena glass, was able to produce the first anastigmat, opening up the field for this type of lens. In 1902 he brought out the Tessar series, with greatly increased speed, and from that time on the development has been continuous.

NODAL POINTS AND OPTICAL CENTER. — Every lens, or lens system, has upon its optical axis a point known as the *optical center*, which lies between two other points known respectively as the *node of admission* and the *node of emergence*. These points are normally within the lens, but with lenses of abnormal construction, such as telephoto lenses, they may be outside. The node of admission is the point from which the distance from the lens to the object is measured, and the node of emergence is the point from which the distance from the lens to the image is measured. In the great majority of photographic objectives, the diaphragm is situated near enough to the optical center to locate it for most practical purposes.

To FIND THE NODAL POINT OF EMERGENCE of a lens, it is rotated on an axis perpendicular to its own optical axis. When a lens that has been focused upon a small, very distant object, is rotated upon such a perpendicular axis, the image will remain fixed only if that axis passes through the node of emergence of the lens. Mount the lens temporarily upon a block through the center of which a nail has been driven to act as a pivot. The lens can then be moved experimentally backwards and forwards, keeping its optical axis over the pivot, until the position is found where the focused image of a distant object does not move when the lens is rotated on the pivot. The node of emergence is then exactly in the axis of rotation. The lens can be turned end for end and the other nodal point found in a similar manner.

CLASSIFICATION OF LENSES. — Lenses are usually classified by focal length, speed, and a name which indicates their optical correction, as, a 2-inch, $f:1.5$, *anastigmat*.

FOCUS AND FOCAL LENGTH. — Strictly speaking a *focus* is a point, that point behind a lens at which it forms a sharp image. The *focal length* of a lens is the distance between the node of emergence of the lens and the focus. The *principal focal length* by which a lens is commonly designated, is its focal length when focused upon an object at infinity, and this is commonly called *equivalent focal length*, *focal length*, or (inaccurately) *focus*. In writing, it is usually abbreviated to the symbol *f*: or *f*/, followed by a designating number, as *f*:4.5. The *back focus* of a lens is the distance between the vertex of the rear lens glass and the groundglass when the lens is focused on infinity, and it is used to calculate the bellows extension necessary when fitting a lens to a camera. For infinity focus, the bellows extension of a camera must be as great as the back focus of the lens, and there must be sufficient additional extension to make it possible to rack the lens out far enough to focus on near objects. In fitting lenses to reflecting cameras, the back focus must be great enough to permit the mirror to clear the rim of the back lens mount when the lens is at infinity focus.

TO FIND THE FOCAL LENGTH OF A LENS. — *By Same Size, and Infinity Focus.* — Any camera with bellows extension enough to make equal size copies will serve, but a view camera with a fixed front in relation to the bed, with back focusing, is most convenient. The back standard should carry a pointer to record the location of the focusing screen with reference to the lens.

First focus sharply upon a very distant, clean-cut object and mark where the pointer rests on the bed. Then focus again on a near object such as a ruled chart or a portion of a foot rule, making the image critically sharp and exactly the same size as the object, and mark the position of the pointer. The distance between the two pointer marks is the focal length of the lens.

By Ratio of Image Size. — The following method is accurate and calls for measurements which are easily made. Focus a foot rule to a definite size on the groundglass, measure the distance between the foot rule and the image, and call this *D*. Then focus to a larger size, again measure the distance as before, and call this *d*. Then the following formula will give the focal length.

$$\frac{d - D}{\left(\frac{r^2 + 1}{r} - \frac{R^2 + 1}{R} \right)}$$

R being the ratio of image to object in the first case, and *r* that in the second case. Example: *D* = 62.7 in.; *d* = 72.2 in.; *R* = 4 and *r* = 5; then $72.2 - 62.7 = 9.5$; then $(5 \times 5 + 1) \div 5 = 26/5$ and $(4 \times 4 + 1) \div 4 = 17/4$; then $26/5 - 17/4 = 19/20$; and $9.5 \div 19/20 = 10$ in., the equivalent focal length of the lens.

By Infinity and Two Lesser Distances. — Focus on a very distant object and mark the extension of the camera; then focus on a comparatively near

object, that is to say, one in the length of an ordinary room, again mark the position of the camera's extension, and call the distance between the two marks x . Again focus on a still nearer object, again measure the distance beyond the infinity mark, and call this distance y . Let B be the distance between the two objects, then the focal length $= \sqrt{Bxy} \div (y - x)$. Suppose the distance of one object is 144 inches and that of the other 96 inches, then $B = 144 - 96 = 48$ and suppose the extension of the camera beyond the infinity or distant mark for the object at 12 feet was 1 inch, and at 8 feet, $1\frac{1}{2}$ inches. Then the focal length $= \sqrt{48 \times 1 \times 1\frac{1}{2}} \div (1\frac{1}{2} - 1) = \sqrt{72} \div \frac{1}{2} = \sqrt{144} = 12$. In this method, if the lens is moved in focusing, the distance between the object at the two positions, or B , must be ascertained by measuring from some part of the camera front. If, on the other hand, the focusing screen is moved and the lens remains stationary, we need only measure the distance between the two positions of the object.

By Focusing an Object Full Size. — Set up a foot rule on a wall, and shift the camera until an image is obtained on the groundglass that is exactly the same size as the rule; naturally how much of the rule is included depends on the size of the groundglass. Then measure the distance between the rule and the image, divide this by 4, and the result will be approximately the equivalent focal length.

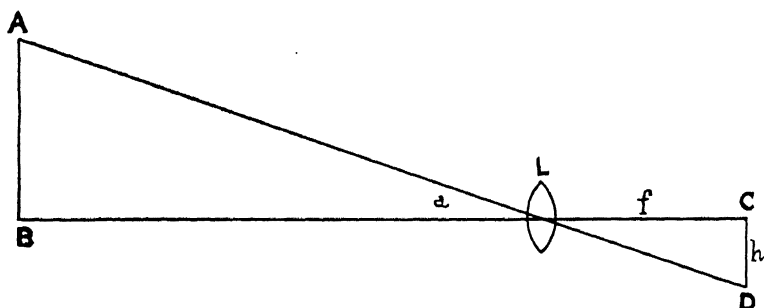
By Focusing to a Definite Scale. — Set up the foot rule as in the previous method, and make the image not more than one-quarter the size of the object; then make a negative of the foot rule, and, calling the distance between the rule and the sensitive plate D , and the ratio of reduction r , which can be found by measuring the length of the image on the negative and dividing into the length of the foot rule, then $f = D \times r \div (r + 1)^2$. Example: a rule of 150 mm was found to give an image of 13.4 mm, D was 800 mm, then $r = 150 \div 13.4 = 11.19$; then $f = 800 \times 11.19 \div (11.19 + 1)^2 = 67.78$ mm.

By Comparing Extensions for Different Distances. — Focus on a near object, then move the object further away from the lens by a distance D , refocus, note the distance through which the focusing screen has been moved, and call this a . Again move the object away from the lens another distance equal to the first distance D , and call the distance the focusing screen has moved b , then the focal length $= \sqrt{2D \times b \times a(b \times a) \div (a - b)}$. The lens must remain stationary in this method. Let $D = 96$, $a = 2$, $b = \frac{1}{2}$; then $f = \sqrt{2 \times 96 \times \frac{1}{2} \times 2(\frac{1}{2} \times 2) \div (2 - \frac{1}{2})} = \sqrt{480 \div 1.5} = 14.61$.

Pinhole Method. — Focus on infinity with the lens, and measure the size of the image. Using a pinhole instead of the lens, produce an image of the distant object exactly the same size as that made with the lens. The distance of the pinhole from the image is the equivalent focal length. A simple thin lens may be used instead of the pinhole.

By Comparison with a Known Focal Length. — If a lens of known focal length is available, it is only necessary to measure the size of the two images, when both lenses are focused on the same distant object, and the focal lengths are proportional to the sizes of the two images.

A Geometrical Method. — Focus two distant objects, as A and B in the diagram, and let C and D be the images of these objects; then $f = h \div \tan a$, a being the angle between AC and BD . Measure the length h , the distance between the images of the two objects, and also CL , their distance from the lens; then $f = h \div (CD \div CL)$. Let CD or $h = 4$ in. and $CL = 8$ in.; then $f = 4 \div (4 \div 8) = 8$.

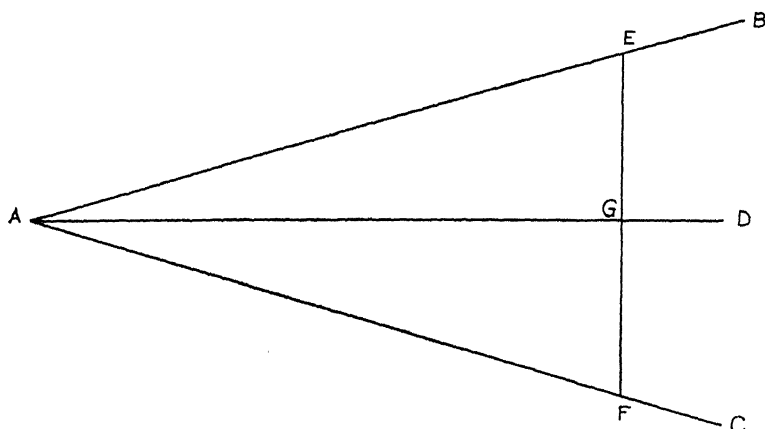


GEOMETRICAL METHOD OF DETERMINING FOCAL LENGTH

Another Geometrical Method. — At a distance a , at least 100 times the focal length, set off at right angles to the axis of the lens two marks one quarter of the distance a from the axis. The distance between the two images on the screen will be half the focal length.

Smith's Method. — This is based on the focusing of the image of a distant object on the lens axis upon the groundglass of the camera, using first the complete lens and then each component separately. The optical rule used is that the focus of a lens of focal length f is at a distance equal to $fF \div f'$ from that of the combination of focal length F , formed by placing in front of the first lens another of focal length f' . Fit the complete lens to the camera, and focus sharply on a distant object. Mark the position of some part of the lens front or moving baseboard against a fixed part of the camera. Now remove the front combination, and again focus on the object, noting the distance d through which the lens front requires to be racked out; this distance is $fF \div f'$ in which F is the focal length of the whole lens and f and f' those of the combinations. Now focus again with the whole lens on the same object, the lens being placed with the back combination to the front. Mark the position as before, then refocus after removing the front combination, really the back one now in front. The distance, d' , between the two positions is $f'F \div f$. Hence $dd' = F^2$, that is to say, by multiplying the two distances d and d' together and extracting the square root, we get the focal length.

Grubb's Method. — At each side of the focusing screen make a pencil mark equidistant from the center. Place the camera flat on a sheet of white paper in front of a window. Focus on a very distant object, so that its image falls exactly on one pencil mark. Then draw a pencil line along the side of the camera, using the edge of the camera as a straight edge. Shift the camera so as to bring the image of the same object on to the other pencil mark on the



GRUBB'S METHOD FOR FINDING FOCAL LENGTH

groundglass, and again draw a line along the side of the camera, using the same side as before. Produce these two lines so that they meet at the point *A*, in the diagram. Bisect the angle *BAC* by the line *AD*, and draw a line *EF* at right angles to this line, equal to the separation of the pencil marks on the groundglass; the focal length is then *AG*.

Lockett's Method. — Draw two short vertical lines at about the center of the focusing screen, exactly 1 inch apart and parallel with each other. Focus sharply on a far distant object and mark carefully on the camera baseboard the exact position of any convenient part of the moving lens front. This may be called the infinity mark. Now measure off 1 inch in advance of this mark, and rack out the camera until the same point of the front is against this 1-inch mark. Fix up a foot rule at about the height of the lens, and move the whole camera to and fro, without any other adjustment, until the rule is in the sharpest possible focus at full aperture and with the commencement, or zero, of the gradations coinciding with one of the pencil lines. Then the number of inches of the rule seen on the groundglass between the two pencil lines will be equal to the focal length of the lens. This method is based on the following reasoning: let *F* be the focal length, and *r* the ratio or proportion between the size of the image and the size of the object; then the minor conjugate focus, or the distance from the lens to the groundglass, is $F + F \div r$. When the camera front is set 1 inch from the infinity mark, then $F \div r$

equals 1 inch, and must also be equal to $F \div F$; therefore $r = F$. It is not essential to adhere to the 1-inch extension, and a greater distance will eliminate errors in measurement, but the distance between the marks on the groundglass must always be the same as the extension of the camera from the infinity mark.

ABERRATIONS OF LENSES.—This is the general term used to designate errors in lenses, or the deviation from an ideal lens of assumed optical perfection taken as a fixed standard set up for reference and as a basis for discussion.

CHROMATIC ABERRATION.—When passing through a lens, white light is broken up into the prismatic colors of which it is composed, and these colors being of different wavelengths of light, come to focus at different distances behind the lens. The more actinic rays, to which the photographic emulsion is principally sensitive, form images which are not coincident with the images of greater visual brightness seen by the eye on the groundglass. This is called chromatic aberration. With some of the very early lenses which were not corrected for this aberration, it was necessary to make an allowance in focusing, as explained on page 8, and with some of the cheap, single lenses used in box cameras the film is made to run in the plane of the chemical, rather than the visual, focus. In *semi-achromatic* lenses, chromatic aberration is only partially corrected so that the resulting images will be intentionally "soft-focus." By combining in a lens optical glasses of the right refractive indices and grinding suitable curves, the planes of sharp focus of at least two of the primary colors are made coincident. All modern photographic lenses are so made. For all ordinary purposes it is necessary to correct for only two colors if the others are brought very close to the common focus. A lens so corrected is called *achromatic*. Which two colors are brought into exact coincidence of focus is determined by the use for which the lens is made. For visual use, as the microscope and field glasses, green and orange are generally chosen because these colors, together with the yellow which lies between them, are the brightest to the eye. For photographic lenses, the colors used are the violet, on account of its actinic activity, and yellow on account of its visual brightness. For three-color process work, it is necessary to correct for the three primary colors so that the resulting negatives will all be equally sharp and of the same size. Lenses corrected for three colors are called *apochromatic*. Such lenses are commonly called *process* lenses, and they have their best correction at near distances, instead of at infinity as in ordinary lenses.

Temporary errors may be found in normal lenses when they are used under abnormal lighting conditions in which there may be a preponderance of certain light rays while others are absent. Such conditions may occur in making portraits with mercury-vapor lamps or enclosed arc lamps. The color correction of the lens may be so much disturbed that visually sharp focusing in one plane may result in photographic sharpness in a different plane.

CORRECTION FOR NON-ACHROMATIC (SPECTACLE) LENSES. — After focusing such lenses, the distance between the lens and the negative must be decreased by approximately one-fortieth the focal length of the lens, in the normal use of the lens when photographing distant objects. In portraiture, copying, etc., where the actual working distance of the lens from the focal plane is greater than the equivalent focal length, the correction must be greater, as follows:

Ratio of reduction	Inf.	1/10	1/5	3/10	4/10	½	6/10	7/10	4/5	same size
Correction (per cent of focal length)	2	2.2	2.4	2.6	2.8	3	3.2	3.4	3.6	4

SPHERICAL ABERRATION. — The spherical curves of a single lens cause the light rays that come through its marginal zones to focus at a shorter distance than do the rays that come through the center of the lens. This trouble can be corrected by sacrificing speed and using a stop so small that only the central rays are utilized. In fast lenses, spherical aberration is optically corrected so that the images formed by the central and the outer zones coincide. This leaves residual aberrations between the central and outer zones, but their effect is negligible. A lens free from all spherical aberrations is called *aplanatic*, but no photographic lens attains such perfection. Corrections can be made only for a given object distance, for which infinity is usually chosen for photographic lenses, and this satisfies most requirements at all other distances. Lenses made for special purposes, as for example for enlarging only, are made with their best correction at the distance at which they will be most used.

COMA. — This is the spherical aberration of pencils of light passing through the lens obliquely. It manifests itself by a one-sided indistinctness increasing towards the margins. Stopping down reduces coma, which takes its name from the comet-like indistinctness of points in the image.

ASTIGMATISM. — This is the inability of a lens to give sharp images of both vertical and horizontal lines that lie in the same plane. The center of the field may be perfect while the margins are defective. Focusing it upon a flat test-chart, or on the courses of a brick wall, will reveal astigmatism in a lens if it exists. Astigmatism is not completely removed by stopping down. Lack of astigmatism gives a lens a larger angular covering power at a definite aperture. Such a lens is called an *anastigmat*. The formation of this word is somewhat complex. Astigmat is in itself a negative word compounded by adding the Greek negative prefix "a" to "stigmat" so that it means non-stigmat. By again adding the negative prefix "a" (an) we get anastigmat meaning "not non-stigmat." The double negative is sometimes dropped, leaving the word *stigmat* which means the same thing as anastigmat. An anastigmat lens has but little curvature of field, and so may be used at large apertures. The image is in a nearly flat plane and therefore the lens is said to have a "flat field." The covering power may be classified into zones, each

one including the previous ones. The first is the circle of good definition at the speed listed; the second is the increased circle of available definition produced when a lens is stopped down; and the third is the light circle, or total light area shown on the focusing screen. Some lenses gain quite regularly in covering power when stopped down, and can be used for wide-angle work. Others gain a little and then stop, for, in some cases, as the circle of available definition grows larger, the light circle contracts.

CURVATURE OF FIELD. — Lenses that are not corrected for curvature of field give an image that does not lie in a flat plane, but on a spheroidal curve or saucer-shaped plane. A flat object cannot be focused by such a lens so that both its center and its margins will be sharp at the same time, unless the lens is stopped down enough to cut off the marginal rays. Curvature of field, or aberration of form, is corrected by making a lens that combines two or more lenses of different curvature and different refractive index.

CURVILINEAR DISTORTION is a defect in a lens that causes straight lines in the object to be reproduced as slightly curved. When a single lens is used with the stop in front of it, straight lines falling near the margins of the picture will appear to be curved towards the margins. With the stop behind the lens, the reverse is the case and the lines are curved inwards towards the center. By placing a lens on either side of the diaphragm, the two distortions correct each other, and the result is a *rectilinear* lens in which straight lines in the subject are reproduced as straight lines in the image.

COVERING POWER is determined by the area which the evenly illuminated flat field covers with perfect definition. It depends upon the diameter of the lens and on the degree to which the different aberrations are corrected. The greater the relative aperture and the greater the covering power, the more useful is the lens.

AIR BUBBLES IN LENSES. — Tiny air bubbles in a photographic lens may be regarded as a mark of quality. Optical glass of certain types cannot be produced without such air bubbles. In the manufacture of such high-grade optical glasses, the melt must be heated for a given length of time at a certain temperature and the process stopped at just the right moment, whether all the gases have been driven out or not. There is no alternative.

The manufacturers discard all but those portions clear and homogeneous enough for lens making, and again examine all glass, both in the rough state and before the lenses are sent out as a finished product. All selections are rigidly made and actual tests prove that small bubbles in lenses, whether single or grouped, do not interfere in any way with the perfect work of the lens. The actual loss of light is inappreciable and the presence of these bubbles, even if near the surface, has no effect whatever on the optical quality of the image.

FLARE SPOTS, or ghosts, are nebulous patches of light caused by reflections. They may originate from spots on a metal iris diaphragm or within the lens

mount where the blackening has worn off, in which case they are easily remedied by repainting the spots with black mat lacquer. Optical flare is caused by reflection of light from the surfaces of the lens and is particularly troublesome if there is a strong source of light near the edge of the field of view. No lens can be free from this trouble, and the greater the number of glass-to-air surfaces, the more possibility of flare. If the lens is dusty, flare will be increased. A change of angle or distance in the viewpoint will often avoid flare, and the use of an efficient lens hood is recommended, especially with all high speed lenses (see page 22).

ILLUMINATION OF NEGATIVE. — A negative can have uniform density only if its margins receive as much light as its center. This is an optical impossibility, because the distance from the lens to the margins of the plate is greater than the distance to its center, but in practice the variation is so slight that it is negligible at ordinary angles of view. With a wide-angle lens, at 90° or more, the variation becomes noticeable, especially with underexposure. Cumbersome mechanical devices have been suggested to remedy this situation, but they never made much popular appeal because with full exposure the latitude of the sensitive emulsion will usually take satisfactory care of all variations in the intensity of the light. Some variation may be caused by the vignetting effect upon the marginal rays by projecting lens mounts, which can be minimized by stopping down the lens. Modern anastigmats are so compactly mounted that they seldom cause trouble in this respect.

The following table shows the added exposure needed at the corners to equalize the light, as worked out by Zscholke for an ideal lens for various angles: —

<i>Angle of lens</i>	<i>Exposure at corners</i>	<i>Angle of lens</i>	<i>Exposure at corners</i>	<i>Angle of lens</i>	<i>Exposure at corners</i>
11°	1.0	62°	1.8	95°	5.0
22°	1.0	70°	2.2	100°	6.0
33°	1.2	77°	2.7	105°	7.0
44°	1.4	84°	3.2	109°	8.9
53°	1.5	90°	4.0		

DEPTH OF FIELD and depth of focus are often confused. Depth of field is the extent of that zone in the field in which the definition is satisfactory. Depth of focus is the ability of the lens to define with satisfactory sharpness upon a plane surface the images of objects situated at varying distances. Depth is increased as the size of the stop is reduced. Theoretically, depth of focus is an impossibility, but in practice, when any object is focused sharply, there is a certain distance in front of and behind the point of focus in which the definition is acceptably sharp. As the degree of sharpness of definition that is satisfactory for one purpose may not be so for another, a standard of definition must be agreed upon before depth of focus can be determined.

DISCS OF CONFUSION. — Rays of light emanating from a point source, when focused by a lens are converged again to a point and are reproduced as such upon a negative situated at the focal plane. Rays emanating from point sources either nearer the lens or farther from it than the point focused upon, cannot produce a point image upon the negative, but give instead a circular disc made by a cross-section of the cone of rays. On account of the limitations of the human eye, these so-called *discs of confusion* appear as point images if the size of their diameters is within a certain tolerance. The size of a disc that appears as a point to the eye varies with the distance at which the image is viewed. The *normal distance of vision* at which a person views an object held in the hand is about 12 inches, and at that distance a disc of not more than $1/100$ inch will appear as a point. That dimension has consequently been quite generally adopted as a satisfactory standard for a *print* that is small enough to be seen best when held in the hand. Larger prints may be satisfied with a larger disc of confusion because they are normally viewed from a greater distance, at which the larger disc still appears as a point to the eye. The standard for a *negative* from which only contact prints are to be made, may be the same as that for the prints, but for negatives from which enlarged prints are to be made, the disc of confusion must be reduced so that its size when enlarged will not exceed the limits mentioned above, if the prints are to be satisfactorily sharp. The resolving power of the eye diminishes in direct proportion to the distance of the object viewed, so that a disc of confusion of $2/100$ of an inch, which would not be satisfactory at a viewing distance of 12 inches, would appear sharp at 2 feet. For this reason it is not necessary that the disc of confusion be reduced in direct ratio to the enlargement contemplated, which would be physically impossible with enlargements of ten or more diameters. But since enlargements from a fraction of the area of the negative are often made to sizes that will be held in the hand, or viewed from a short distance, a margin of safety in regard to the size of the disc of confusion should be maintained. A uniform standard of definition in enlarging is automatically maintained by establishing the value of the disc of confusion as $1/1000$ of the focal length of the taking lens, instead of using any arbitrary figure whose results vary with different focal lengths.

SPEED OF LENSES. — Although somewhat affected by the amount of light lost in them by absorption and reflection, the speed of lenses depends primarily upon the area of the circle of light that they admit to the camera, and the distance that this light has to travel after passing through the lens until it comes to focus. The maximum amount of light admitted is governed by the largest stop at which the lens will work; the distance it has to travel is indicated by the focal length of the lens. As the areas of circles vary as the square of their diameters, the greatest possible amount of light admitted is in direct proportion to the square of the diameter of the largest stop. This is calculated from the effective aperture, not the actual diameter of the dia-

phragm. As the strength of the admitted light varies inversely as the square of the focal length of the lens (the distance it has to travel), its effective value

may be written $\frac{d^2}{f^2}$, or $\left(\frac{d}{f}\right)^2$ where d = diameter of stop, and f = focal

length of the lens. The speeds of lenses are rated from this ratio, but for convenience what is listed is not the effective value of the light, but the exposure needed with that amount of light, which, of course, is in indirect ratio

to the value of the light. Hence, $\frac{f}{d}$ is used and the result of this division is

written as the f number. For example, a 10-inch lens with an effective aperture of 2 inches would be $\frac{10}{2}$ 4.5, and the lens would be listed $f:4.5$.

As noted above, the factors from which this ratio was derived, vary as their squares, so the speeds of lenses are compared by comparing the squares of their f numbers. A lens listed as $f:2$ would be five times as fast as one listed as $f:4.5$, because the ratio of their speeds would be the same as that of the squares of their f numbers, which are 4 and 20.25.

THE RESOLVING POWER OF LENSES depends upon the degree to which their aberrations have been optically corrected. Every lens has one approximate aperture at which it theoretically gives the sharpest definition. With anastigmats this is very often its largest aperture unless otherwise stated by the manufacturer. The difference between the sharpness at this and neighboring apertures on a good lens is negligible for ordinary work and so slight that it can be determined only upon an optical bench in a laboratory. Stopping down an anastigmat lens does not necessarily improve its sharpness except as it increases the depth of field and thereby compensates for possible errors in focusing. At abnormally small apertures, diffraction causes lack of definition. This is governed by the actual, rather than the relative, size of the aperture; so that the minimum usable aperture ratio varies with the focal length of the lens. The manufacturer usually takes care of this problem by supplying the lens with no smaller stop than can be used efficiently.

Aberrations in even the best lenses are not perfectly corrected and they really, under microscopic observation, result in a slight blur instead of the theoretical point image. As these blurs have a maximum intensity on a small part of their area, definition is usually better when a minimum rather than a full exposure is given. Photographic emulsions vary in their ability to record fine definition, but the sharpness of a photograph is usually limited by the ability of the emulsion to record fine definition, rather than by the resolving power of the lens. Even under optima conditions of exposure and processing most emulsions have less resolving power than that of the anastigmat lenses regularly supplied with the better grade of cameras (see page 8).

HYPERFOCAL DISTANCE. — When a lens is focused upon infinity, the light rays reaching the lens are practically parallel. The object nearest to the lens which is sufficiently sharp on the focusing screen to satisfy the standard of definition that has been selected is said to be at the hyperfocal distance, and depth of definition extends from this point onward to infinity. If the hyperfocal point is focused upon, the nearest object in focus is then at half the hyperfocal distance from the lens and the farthest object is at infinity, so that the depth of field now reaches from half the hyperfocal distance to infinity. This fact is of very practical use in landscape and view work, especially with scale-focusing cameras.

The hyperfocal distance for any lens of any given focal length and any stop may be found by the following formula:

$$Hf = \frac{f^2 \times D}{a}$$

in which Hf represents the hyperfocal distance, f is the equivalent focal length of the lens, D is the denominator of the fraction of an inch that has been agreed upon as the acceptable size of the disc of confusion, and a is the denominator of the fraction designating the diameter of the stop. To find the hyperfocal distance for a 5-inch lens used at $f:8$, with a disc of confusion of $1/100$ of an inch: $Hf = \frac{5 \times 5 \times 100}{8} = \frac{2500}{8} = 312\frac{1}{2}$ inches or,

approximately, 26 feet. When $1/1000$ of the focal length is taken as the disc of confusion, the hyperfocal length is easily found by multiplying the focal length by 1000 and dividing by the aperture number. Thus, in the above problem $5000 \text{ inches} \div 8 = 625 =$ approximately 52 feet, the hyperfocal distance in this case being twice that in the former because the disc of confusion used is half as great, ($1/1000$ of $5 = 1/200$).

The hyperfocal distance depends upon the *actual* diameter of the stop. With the same actual size of stop, the hyperfocal distance is the same for any lens, regardless of its focal length. Thus, with a 2-inch lens at $f:2$, a $3\frac{1}{2}$ -inch lens at $f:3.5$, and an 8-inch lens at $f:8$, the actual diameter of the stop is 1 inch in each case, and the hyperfocal distance is the same for them all, if it is desired to produce the same sized disc of confusion *on the negatives*. It must be remembered that negatives made with shorter focal length lenses are usually proportionally enlarged and the disc of confusion must be correspondingly reduced to allow for this. For this reason it is wise to calculate the disc of confusion proportionately to the focal length of the lens as described above.

In *THE AMERICAN ANNUAL OF PHOTOGRAPHY* for 1940, Mr. Hans A. Eriksen gave the following table of the actual diameter of the relative apertures of lenses up to 5 inches, and points out that for a standard of definition of $1/120$ inch viewed at 10 inches, the hyperfocal distances in feet can be

read directly from this table. A disc of confusion of $1/120$ inch at 10 inches subtends an angle of $1/1200$ of a radian, and as there are 100 feet in 1200 inches, the values in the table multiplied by 100 will equal the corresponding hyperfocal distances measured in feet.

TABLE OF LENS DIAMETERS

<i>Focal length (inches)</i>	<i>f:2</i>	<i>f:2.7</i>	<i>f:4</i>	<i>f:5.6</i>	<i>f:8</i>	<i>f:11</i>	<i>f:16</i>	<i>f:22</i>
<i>Diameter of aperture in decimal fractions of an inch</i>								
$1\frac{1}{2}$	0.75	0.56	0.38	0.27	0.19	0.14	0.09	0.07
2	1.00	0.74	0.50	0.36	0.25	0.18	0.12	0.09
$2\frac{1}{2}$	1.25	0.93	0.62	0.45	0.31	0.23	0.16	0.11
3	1.50	1.11	0.75	0.54	0.38	0.27	0.19	0.14
$3\frac{1}{2}$	1.75	1.30	0.88	0.62	0.44	0.32	0.22	0.16
4	2.00	1.48	1.00	0.71	0.50	0.36	0.25	0.18
$4\frac{1}{2}$	2.25	1.67	1.12	0.80	0.56	0.41	0.28	0.20
5	2.50	1.85	1.25	0.89	0.62	0.45	0.31	0.23

From the above table it can be seen at a glance that the hyperfocal distance with a disc of confusion of $1/120$ inch, when viewed at 10 inches for a 2-inch lens working at $f:2$, is 100 feet, while if it were stopped down to $f:22$, the hyperfocal distance would be 9 feet. The hyperfocal distance for smaller discs of confusion can be read by taking the readings for a lens of proportionately longer focus. For example, in the above case, if it is desired to use a disc of confusion of $1/150$ inch, which is 25 per cent smaller than $1/120$ inch, the readings are taken for a $2\frac{1}{2}$ -inch lens.

TABLE OF HYPERFOCAL DISTANCES IN FEET

Calculated by Arnold Rostron for a disc of confusion $\frac{1}{1000}$ the focal length of lens.

<i>Focal Length (Inches)</i>	<i>Focal Ratio (Stop Number)</i>												
	<i>f:1</i>	<i>f:1.5</i>	<i>f:2</i>	<i>f:2.5</i>	<i>f:3</i>	<i>f:3.5</i>	<i>f:4.5</i>	<i>f:5.6</i>	<i>f:8</i>	<i>f:11</i>	<i>f:16</i>	<i>f:22</i>	<i>f:32</i>
1	83	56	42	33	28	24	19	15	10	8	5	4	...
$1\frac{1}{2}$	125	83	62	50	42	36	28	22	16	11	8	6	4
2	167	110	83	67	56	48	37	30	21	15	11	8	5
$2\frac{1}{2}$	210	140	110	83	69	60	46	37	26	19	13	10	7
3	...	170	125	100	83	71	56	45	31	23	16	11	8
$3\frac{1}{2}$	...	200	150	120	100	83	65	52	37	27	18	13	9
4	...	...	170	130	110	95	74	60	42	30	21	15	10
$4\frac{1}{2}$	...	...	190	150	125	110	83	67	47	34	24	17	12
5	...	...	...	170	140	120	93	74	52	38	26	19	13
$5\frac{1}{2}$	...	...	...	185	150	130	100	82	57	42	28	21	14
6	...	...	...	200	165	145	110	89	63	46	31	23	16
$6\frac{1}{2}$	...	...	...	215	180	155	120	97	68	49	34	25	17
7	...	...	...	235	195	165	130	105	73	53	37	27	18
8	...	...	...	...	...	190	150	120	83	61	42	30	21

SHORT RULES ABOUT DEPTH. — Depth increases, first, as the distance of the object from the lens *increases*; second, as the focal length of the lens *decreases*; third, as the lens is stopped down.

FOCUSING RULES FOR HAND CAMERAS. — Two simple rules may be used with hand cameras. When the background is not very distant, focus on a distance equal to twice the product of the greatest and shortest distances, divided by their sum. With one object at 20 yards and another at 5 yards, $\frac{2 (20 \times 5)}{20 + 5} = 8$ yards, the distance to be focused upon. When an object is comparatively near and the background is infinity or very distant, focus on a point double the distance of the nearest object.

COMBINING LENSES. — To find the focal length of two lenses separated by a short distance, multiply the focal lengths together and divide by their sum less the distance of separation. Let f' and f'' be the focal lengths and d the separation of the two lenses; then the final focal length will be:

$$\frac{f' \times f''}{f' + f'' - d}$$

Example: a 6-inch lens and an 8-inch lens are to be combined with a distance of separation of 1 inch; the focal length will be:

$$\frac{6 \times 8}{6 + 8 - 1} = \frac{48}{13} = 3\frac{1}{2} \text{ inches.}$$

SUPPLEMENTARY LENSES. — To find the necessary focal length of a supplementary lens or magnifier, to reduce or increase the focal length of a lens by a given amount, multiply the original focal length that is to be altered by the focal length desired, and divide the product by the original focal length less the desired focal length. Example: to reduce a 10-inch lens to 7 inches,

then $\frac{10 \times 7}{10 - 7} = \frac{70}{3} = 23\frac{1}{3}$. To reduce the focal length, positive and convex

lenses are used, and, in this case, the focal length of the lens to be added is prefixed by the minus sign in the formula. Example: to lengthen a 7-inch lens to 10 inches, $7 \times 10 = 70$; and $7 - (+10) = -3$; and $70 \div -3 = -23\frac{1}{3}$.

In these calculations, the separation of the lenses has been neglected because only approximations are possible, as the lens and the supplementary lens cannot be brought into so-called "nodal contact."

With fixed-focus cameras, the focal length of a magnifier for reducing the combined focal length (to make it possible to photograph objects close to the camera when the lens cannot be racked out) must be equal to the distance of the object from the camera.

DIOPTERS. — The power of a lens is measured in diopters. A diopter is the reciprocal of the focal length in meters. This term is commonly used with spectacle lenses and supplementary lenses.

THE ANGLE OF VIEW of a lens is found by dividing the diameter of its field

by its focal length. The quotient, which is mathematically twice the tangent of half the angle, may be looked up in a table of view-angles such as that which follows. The angle of view is usually considered to be the angle included by the longer side of the negative rather than by the diagonal.

TABLE FOR FINDING VIEW-ANGLES. — Divide the horizontal width of the picture area between the vertical limits, by the focal length of the lens:

<i>If the quotient is</i>	<i>the angle is</i>	<i>If the quotient is</i>	<i>the angle is</i>	<i>If the quotient is</i>	<i>the angle is</i>	<i>If the quotient is</i>	<i>the angle is</i>
.0174	1	.65	36	1.063	56	1.56	76
.0872	5	.67	37	1.086	57	1.59	77
.1749	10	.689	38	1.108	58	1.62	78
.2633	15	.708	39	1.132	59	1.649	79
.353	20	.728	40	1.155	60	1.678	80
.371	21	.748	41	1.178	61	1.7	81
.389	22	.768	42	1.2	62	1.739	82
.407	23	.788	43	1.225	63	1.769	83
.425	24	.808	44	1.25	64	1.8	84
.443	25	.828	45	1.274	65	1.833	85
.462	26	.849	46	1.3	66	1.865	86
.48	27	.875	47	1.32	67	1.898	87
.5	28	.89	48	1.36	68	1.931	88
.517	29	.911	49	1.375	69	1.965	89
.536	30	.933	50	1.4	70	2.	90
.555	31	.954	51	1.427	71	2.182	95
.573	32	.975	52	1.45	72	2.38	100
.592	33	1.	53	1.48	73	2.464	110
.611	34	1.02	54	1.5	74	2.856	120
.631	35	1.041	55	1.53	75		

Example: Using an 8-inch lens for a 5 by 7 plate, the horizontal angle is $7 \div 8 = 0.875$. From the table, we see that the angle is 47° . The vertical angle is worked out as follows: $5 \div 8 = 0.625$, so, from the table we find that the angle is between 34° and 35° . To find the angle on the diagonal, which we find from the following table is 8.6 for a 5 by 7 negative, we divide 8.6 by 8 which gives a quotient of 1.075, for which the angle is just a little more than 56° .

DIAGONALS OF NEGATIVES

<i>Size</i>	<i>Diagonal</i>	<i>Size</i>	<i>Diagonal</i>
$\frac{3}{4}$ by 1	1.3 inches	$3\frac{1}{4}$ by $5\frac{1}{2}$	6.4 inches
1 by $1\frac{1}{2}$	1.8 "	$3\frac{1}{2}$ by $3\frac{1}{2}$	4.9 "
1 $\frac{3}{16}$ by 1 $\frac{9}{16}$	2. "	4 by 5	6.4 "
$1\frac{1}{2}$ by 2	2.5 "	$4\frac{1}{4}$ by $6\frac{1}{2}$	7.8 "
$1\frac{1}{2}$ by $2\frac{1}{4}$	2.7 "	5 by 7	8.6 "
$1\frac{5}{8}$ by $2\frac{1}{4}$	2.8 "	5 by 8	9.4 "
$1\frac{3}{4}$ by $2\frac{1}{4}$	2.9 "	$6\frac{1}{2}$ by $8\frac{1}{2}$	10.7 "
$2\frac{1}{4}$ by $2\frac{1}{4}$	3.2 "	7 by 9	11.4 "
$2\frac{1}{4}$ by $3\frac{1}{4}$	3.9 "	8 by 10	12.8 "
$2\frac{1}{2}$ by $3\frac{1}{2}$	4.3 "	10 by 12	15.6 "
$2\frac{1}{2}$ by $4\frac{1}{4}$	4.9 "	11 by 14	17.8 "
$2\frac{7}{8}$ by $4\frac{3}{8}$	5.6 "	12 by 15	19.2 "
$3\frac{1}{4}$ by $3\frac{1}{4}$	4.6 "	14 by 17	22. "
$3\frac{1}{4}$ by $4\frac{1}{4}$	5.3 "	16 by 20	25.6 "

DIAGONALS OF METRIC SIZES AND EQUIVALENTS

<i>cm</i>	<i>inches</i>	<i>diagonals</i>	
2.4 by 3.6	1 by 1.5	4.3 cm	1.8 inches
3 by 4	1.2 by 1.5	5 "	1.92 "
4 by 4	1.5 by 1.5	5.7 "	2.3 "
4 by 6.5	1.5 by 2.6	7.6 "	3 "
4.5 by 6	1.8 by 2.4	7.5 "	2.9 "
(stereo) 4.5 by 10.7	1.8 by 4.2	11.6 "	2.3 "
6 by 6	2.4 by 2.4	8.5 "	3.4 "
6 by 9	2.4 by 3.5	10.8 "	4.3 "
6.5 by 8.9	2.6 by 3.5	11.1 "	4.6 "
9 by 12	3.6 by 4.7	14.9 "	5.9 "
11 by 15	4.3 by 5.9	18.6 "	7.3 "
12 by 16	4.7 by 6.3	20.1 "	7.9 "
12 by 20	4.7 by 7.8	23.3 "	9.2 "
13 by 18	5.1 by 7.1	22.1 "	8.7 "
15 by 21	5.9 by 8.3	26 "	10.2 "
18 by 24	7.1 by 9.5	30.1 "	11.9 "
21 by 27	8.3 by 10.7	34.2 "	13.5 "
30 by 40	12 by 16	50 "	20 "

EFFECTIVE RATIO APERTURE OF DIAPHRAGMS.—The *effective* aperture of the stops of compound lenses does not coincide with the *actual diameter* because of the condensation of the light by the front lens component in compound lenses. To determine the correct effective aperture (Steinheil), focus the lens for parallel rays, that is, on a very distant object, then replace the focusing screen with an opaque card, in the center of which is a pinhole. In a dark room, place a light behind the pinhole, and a circle of light will be found on the front glass of the lens; the diameter of this circle will be the effective aperture of the stop, and dividing the focal length by this, gives the true aperture or stop value. As it is sometimes difficult to see the circle of light on the glass, the latter may be dusted with any white powder, which makes the light more readily visible. Or a small piece of bromide paper may be cut and placed inside the cap of the lens, and a fairly long exposure given to the light passing through the pinhole and the lens. On development, the diameter of the black circle is the diameter of the effective aperture. Another method is to focus a bright spot of light at infinity, or a great distance, and then move the focusing screen until the spot of light becomes a disc of any definite diameter, say, half an inch. Then the distance the focusing screen was moved, divided by the diameter of the disc of light, is the diameter of the aperture. Opticians have special devices by means of which the magnified diameter of the stop is measured directly. To find the diameter of the stops for a lens, the following approximate method may be adopted: find the equivalent focus, f , of the lens, and measure the distance between the two outer surfaces of the front and back lens, calling this d ; then the diameter of the stop $f:x$ will be $(f - \frac{1}{2}d) \div x$. Example: the focal length of a lens is 16 inches and the distance between the inner and outer surfaces is 2 inches;

the diameter of the stop $f:8$ will be $\frac{16 - 1}{8} = \frac{15}{8} = 1\frac{7}{8}$ inches.

The effective aperture of a single lens with the diaphragm in front is the actual diameter of the diaphragm. When a single lens of a doublet is used in front of the diaphragm, the effective aperture of that lens is greater than the actual diameter of the diaphragm, which is the reason why a single element of a Goerz Dagor, when used in front of the diaphragm, works at $f:11.3$ as compared with $f:13.6$ when it is behind the diaphragm, a gain of almost 50 per cent in illumination. If an iris diaphragm is opened up to a certain stop as indicated by the pointer, and then closed down to the same mark, there will be a slight variation due to the backlash and the play in the iris blades. Such discrepancies do not materially affect the exposure.

VARIATION OF f VALUES.—When copying or enlarging, or when photographing very near objects, the lens is racked far beyond infinity and the actual focal length is increased, so that the values of the stops are altered. For critical work the aperture value has to be computed upon the ratio between the effective size of the stop and the actual distance between the lens and the focal plane.

STOP APERTURE SYSTEMS.—Various systems have been suggested from time to time for numbering the diaphragms or stops, but, practically, only two have survived. In the f or ratio system, which is now almost universally used, the effective aperture is expressed as a fraction of the equivalent focus, as $F:8$, $F/8$ or $f:8$, which means that the aperture of the stop is one-eighth of the equivalent focus. The older system, known as the U. S. or Uniform System, is based on $f:4$ as unity, and the stops are merely numbered in fractions and multiples of this. The following table shows the relation of the two systems:

	<i>U. S. No.</i>		<i>U. S. No.</i>
$f:1$	$\frac{1}{4}$	$f:12$	9
$f:1.414$	$\frac{1}{2}$	$f:16$	16
$f:2$	$\frac{1}{2}$	$f:22.62$	32
$f:2.828$	$\frac{1}{2}$	$f:28$	49
$f:3$	0.562	$f:32$	64
$f:4$	1.	$f:36$	81
$f:5$	1.56	$f:40$	100
$f:5.656$	2.	$f:45.25$	128
$f:6$	2.25	$f:56$	196
$f:7$	3.06	$f:64$	256
$f:8$	4.	$f:70$	306.25
$f:9$	5.06	$f:80$	400
$f:10$	6.25	$f:90.5$	512
$f:11.31$	8.	$f:100$	625

Stolze proposed $f:10$ as unity, and Dallmeyer $\left(\frac{1}{3.16}\right)$. The Paris Congress

also adopted $f:10$ as the unit. Zeiss adopted $f:100$ as unity, so that the larger stops were marked with the relative luminosity, which gave as a fraction the relative exposures; for instance, $f:6.3$ was 256, and the exposure compared to that for $f:100$ was $1/256$. All these systems have practically fallen into disuse in England and America, the ratio system alone being used.

COMPARATIVE SPEED OF STOPS. — As the speed of stops (diaphragm apertures) depends upon the area of the circle of light that they admit, their speed varies in direct proportion to the square of their diameters, so comparative speed of stops is found by comparing the squares of their f : numbers. The ratio between $f:8$ and $f:4$ is therefore $8^2:4^2 = 64:16$ and the exposure needed at $f:8$ is four times as long as at $f:4$. The Royal Photographic Society of Great Britain, in 1881, advocated the use of standard stops of such size that each successive stop would require twice the exposure of the preceding one. The series selected was

4 5.6 8 11.3 16 22.6 32 45 64

which required relative exposures of

1 2 4 8 16 32 64 128 256

With increased speed in lenses, this series has been extended to 1.5, 2, and 2.8 which require relative exposures of approximately $\frac{1}{8}$, $\frac{1}{4}$, and $\frac{1}{2}$ as compared to the exposure of 1 for $f:4$, at which point they connect with the older series. The speeds of 3.2, 4.5, 6.3, 9, and 12.5, while they do not tie in with the older series, preserve the same ratio between themselves, each successive stop requiring approximately twice the exposure of the preceding one.

LOSS OF LIGHT IN LENSES. — While it is true in general that the comparative speed of lenses varies as their relative apertures, there is a varying amount of light lost in different lenses by absorption and reflection by the glass, so that the actual intensity of the image may differ considerably among lenses marked with the same f number. Loss by *absorption* is largely confined to the ultra-violet region, where such loss is an advantage photographically. The loss in visible rays is usually very slight, although it may be considerable with old lenses which have a yellow coloration. Loss of light by *reflection* from glass-to-air surfaces of elements is greater, and increases with the number of such elements of which the objective is composed. Its effect may be greatly reduced by the use of an efficient lens hood. The losses of light from both absorption and reflection vary from about 10 per cent in a simple single lens, to as much as 50 per cent in some of the more complex objectives. While modern anastigmats do not usually transmit more than 65 per cent of the incident light, most of them are so closely grouped in this respect that the difference between them is negligible for ordinary work, and their speeds may be compared with a fair degree of accuracy by their f

ratings. By far the greatest loss of light in lenses is caused by dirt on the lens, or by dulling of the polish by too vigorous cleaning.

TELEPHOTO LENSES. — If a negative lens is fitted in front of a positive lens (such as is ordinarily used for making photographs) the result will be a telephoto lens. The equivalent focal length of this combination will be greater than that of the positive lens, but the camera extension needed to bring the combination to a focus will be less than the equivalent focal length. This makes a convenient way of getting larger images with cameras whose extension is too short to accommodate long focus lenses.

Let M be the magnification, i.e., the number of times the image produced by the complete lens is larger than that produced by the positive lens alone; f the focal length of the complete lens; f' the focal length of the positive lens; f'' the focal length of the negative lens; E the camera extension from negative lens to plate. To find the magnification (M), divide the camera extension by the focal length of the negative lens, and add 1, or $M = (E \div f'') + 1$. To find the camera extension, multiply the focal length of the negative lens by the magnification minus 1, or $E = f'' (M - 1)$. The focal length of the whole lens for distant objects equals the focal length of the positive lens multiplied by the magnification, or $f = Mf'$. For near objects when reducing N times, $f = (mE + f') \div (mN + 1)$, in which $m =$ the ratio of f' to f'' , i.e., $f' \div f''$ (Dallmeyer).

Assume the same notation as above. The separation of the positive from the negative lens equals $(f' - f'') \div (f'' \div M)$. Example: suppose the positive lens has a focal length of 7 inches and the negative lens 3 inches, the separation for four magnifications will be $(7 - 3) \div (3 \div 4) = 4\frac{2}{3}$. An alternative formula giving the separation necessary to obtain a telephoto combination of a desired focal length is $(f' - f'') \div f' (f'' \div F)$. Example: if the positive lens is 9 inches focus and the negative lens 4 inches, the separation required to make the combined focus 16 inches will be $(9 - 4) \div 9 \times (4 \div 16) = 5 \div 9 \times \frac{1}{4} = 5 \div 2\frac{1}{4} = 7\frac{1}{4}$. Where a scale of magnification is marked, as on the ordinary type of adjustable mount, and another magnification is desired that is not marked, let M' stand for any existing marked magnification and M'' for the magnification desired. Then $f'' \times (M' - M'') \div (M' \times M'')$ will be the increase of separation required. Example: suppose a magnification of 5 is wanted, and the nearest mark is 3, the focus of the negative lens being $4\frac{1}{4}$. Then $4\frac{1}{4} \times (5 - 3) \div (5 \times 3) = 4\frac{1}{4} \times 2/15 = \frac{2}{3}$ inches, which is the necessary extra separation readily measured from the existing mark for three magnifications. When the focal length of the negative lens is unknown, it is easy to find it from the distance between any two magnifications marks on the mount. The rule is: multiply the two magnifications together and divide by their difference, multiplying the quotient by the distance D between the two marks; $(M' \times M'') \div (M' - M'') \times D$. Example: suppose the distance between the marks 8 and 4 on a tele-

photo mount is $\frac{3}{4}$ inch, then $(8 \times 4) \div (8 - 4) \times \frac{3}{4} = 32/4 \times \frac{3}{4} = 6$ inches, which is the required focal length (Lockett).

The covering power on low magnifications like 3 and 4 may not be as great as that of the positive lens used alone. On the higher magnifications, much larger areas are easily covered than can be covered with the positive lens alone.

FOCAL-PLANE SHUTTERS. — The curtain of a focal-plane shutter is usually made of rubberized cloth and should be treated with reasonable care. When the camera is not in use, the curtain should be released and left at the lowest tension. If the rollers need to be oiled, no oil should be allowed to remain on the curtain, as it will have a deleterious effect on it. Sluggishness of a focal-plane shutter in very cold weather may be due to stiffening of the rubber cloth, or to the oil having congealed. If a focal-plane camera is not kept in a case, a plate holder or some other adapter should be left in place at the back to protect the shutter curtain. If the camera is left with the back open and the shutter at its widest opening, the inside of the camera is exposed to dust and dirt; if the shutter is closed, the curtain is liable to be damaged.

Focal-plane cameras are subject to a peculiar danger if set down outdoors with the lens facing the sun. If the mirror happens to be up and the lens is focused on infinity it will act like a burning glass and will burn a hole in the rubber curtain.

Pinholes in the curtain may be repaired by dissolving rubber in chloroform to a creamy consistency and adding an equal amount of black asphaltum varnish or some other similar blackening ingredient. This mixture is applied to the pinholes with a stick and that section of the curtain should not be rolled up until the solution thus applied has had time to dry.

BRIGHT NEGATIVES. — An important optical factor in obtaining bright, fogless negatives is the protection of the lens from all extraneous light. An efficient lens hood which shuts off all side light from the lens will greatly increase the brilliancy of negatives. The hood should completely surround the lens, and should be at least half as long as its focal length. Efficient lens hoods are made for view and portrait cameras, but the commercial article for hand cameras, in the interest of easy portability, is usually made too short for greatest efficiency. An efficient hood can be made from soft leather according to the diagram on the next page.

Direct sunlight shining on the lens gives off light in every direction, and may cause a haze inside the camera which will fog the negative.

Another cause of fog is a bright spot on the inside of the lens mount where the black has flaked off, or on the edge of a diaphragm blade where the black has been rubbed off. Such bright spots must be blackened.

The inside of the bellows scatters light, especially when the lens used is one of greater covering power than is needed. A bellows diaphragm may be made of cardboard covered with black velvet or paper, just the right size

to fit into one of the folds of the bellows and with an opening cut in it the same shape as the area to be covered and just the right size so that no light except that used to form the image can reach the sensitive surface of the emulsion. This can be pushed into place when the bellows is fully extended and the folds in the bellows will hold it.

The diagram below shows how to make an efficient leather lens hood.

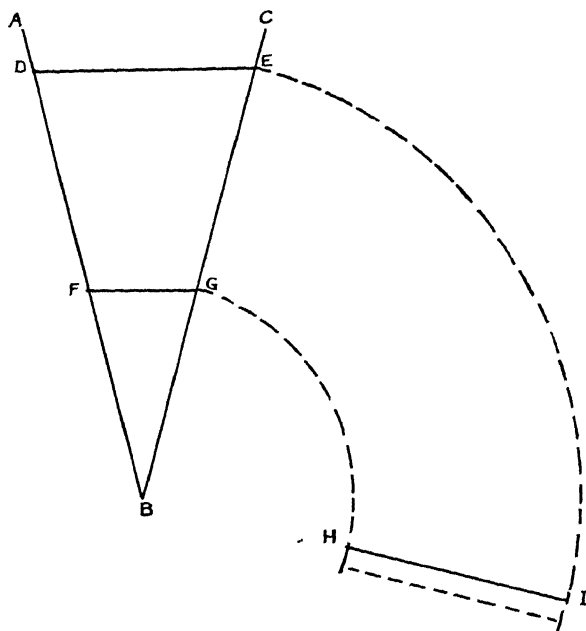


DIAGRAM OF LENS HOOD

ABC = Angle of View of Lens.

FG = Diameter of Outside of Lens Barrel.

FD = Desired Length of Lens Hood.

EI = $DE \times 3.1416$ (arc described by using B as a center).

GH = $FG \times 3.1416$ (arc described by using B as a center).

Figure $EIHG$ is the pattern for the lens hood, to which should be added enough for an overlap for sewing the edges together. Sew together so that GH makes a tight fit over lens barrel. The outer edge is stiffened with millinery wire which is covered with black silk. If a loop of wire is simply hinged on the outer edge of the lens hood and a strip of leather sewn around the edge, against which the wire may seat, the wire can be folded back into the hood, which can then be collapsed for convenient carrying.

CONJUGATE FOCI.—When a lens is focused upon an object nearer than infinity the distance between the lens and the object, and the distance between the lens and the image are called *conjugate foci*. These distances bear a fixed relationship to each other, and can be found by calculation, and they are useful in enlarging and reducing. In enlarging, the distance from the

lens to the easel is the *major conjugate* and is found by multiplying the focal length of the lens by the times of enlargement plus 1. The distance from the lens to the negative is the *minor conjugate*, and is found by dividing the major conjugate by the times of enlargement. Let F equal the focal length of the lens, d the minor conjugate, D the major conjugate, and R the times of enlargement. Then $D = F (R + 1)$ and $d = \frac{D}{R}$.

The general formula for conjugate foci is $\frac{1}{F} = \frac{1}{d} + \frac{1}{D}$ and from this formula, if any two of the terms are known, the other can be found. To be optically accurate, conjugate foci must be measured from the node of admission and from the node of emergence, but the space between the nodes is generally so small that it is negligible under ordinary working conditions. Hence, in enlarging to scale, it is usually satisfactory to calculate the major and minor conjugate foci, add them, and set the negative and easel this distance apart, and then focus the lens visually. Conjugate foci are useful to calculate the working distance needed when operating with a lens of a given focal length. For example, to produce a 6-inch image of a man 72 inches tall, with a 10-inch lens, we note that the ratio between the object and the image is 12, and from our first formula we find that the major conjugate, D is $10 (12 + 1) = 130$ inches; the minor conjugate is 130 divided by 12 (the times of enlargement) $= 10\frac{2}{3}$ inches.

For ordinary degrees of enlargement with lenses up to 12 inches, these distances have been figured out and appear in the table on page 146.

DISTANCES FROM LENS TO SUBJECT *for an average standing figure of 68 inches.* Figures given in the table are distances in inches from the lens to the subject.

Focal length of lens used	Heights of image on groundglass								
	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.
2	70								
3	105	71							
4	140	95	72						
5	175	118	90	73					
6	210	142	108	88	74				
7	245	166	126	102	86	75			
8	280	189	144	117	99	86	76		
9	315	213	162	131	111	96	86	77	
10	350	237	180	146	123	107	95	86	78
11	385	260	198	171	135	118	105	94	86
12	420	284	216	175	148	129	114	103	94
13	455	308	234	190	160	139	124	111	101
14	490	331	252	204	173	150	133	120	109
15	525	355	270	219	185	161	143	128	117
16	560	379	288	234	197	171	152	136	125
17	595	402	306	248	210	182	162	145	133
18	630	426	324	263	221	194	171	154	140
19	665	450	342	277	234	203	181	163	148
20	700	473	360	292	247	214	199	171	156

For a child only about half this height, these figures can be halved. The above are actual distances between the lens and the subject and do not allow for any working space for the operator or space between the subject and the background. These extra distances must be allowed for in estimating the total length of a studio.

DISTANCES FROM LENS TO SUBJECT *for an average head of 9 inches.* Figures given in the table are distances in inches from the lens to the subject.

Focal length of lens used	Heights of image on groundglass								
	1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	9 in.
2	20	11							
3	30	17	12						
4	40	22	16	14					
5	50	28	20	18	14				
6	60	33	24	21	17	15			
7	70	38	28	25	19	18	16		
8	80	44	32	28	22	20	18	17	
9	90	50	36	32	25	23	21	19	18
10	100	55	40	35	28	25	23	21	20
11	110	61	44	39	31	28	25	23	22
12	120	66	48	42	34	30	28	25	24
13	130	72	52	46	36	33	30	27	26
14	140	77	56	49	39	35	32	29	28
15	150	83	60	52	42	38	36	32	30
16	160	88	64	56	45	40	37	34	32
17	170	94	68	60	48	43	39	36	34
18	180	99	72	63	50	45	41	38	36
19	190	105	76	67	53	48	44	40	38
20	200	110	80	70	56	50	46	42	40

To insure correct drawing, and to avoid distortion, lenses for portraiture should be of comparatively long focal length, not less than 14 to 16 inches for an 8 by 10 negative, and longer if possible.

UNSCREWING LENSES AND SHUTTERS. — A lens that sticks in the lens flange can sometimes be unscrewed by placing a block of artgum or soft artists' eraser over the front end and squeezing it down on the cell rim. The hand gripping the lens and rubber can apply considerable force safely and the rubber will not slip, especially if the front rim is milled. A few drops of kerosene placed on the thread junctions and allowed to stand for a few hours will sometimes loosen a stuck thread.

Considerable force may be safely applied to unscrewing a lens when the threads have become tightly stuck, as by the action of salt-laden air at the seacoast, by using a "Spanish windlass," made by winding the lens with electricians' friction tape and leaving a loop of several thicknesses of the tape protruding, through which a stout stick is inserted and used as a lever.

Shutters of lenses that are attached to metal camera fronts by locking rings are easily detached by a spanner wrench with a stiff metal piece that straddles the glass and engages in the notches cut across the locking ring or lens cell,

some of which are fitted with notched cell rims. Attempts to drag such rings around with a screwdriver in these notches may cause serious damage to the lens if the screwdriver slips.

When a lens flange or a lens cell is to be engaged in the threads on the lens, the lens and the flange should be slowly rotated *backwards* until a slight click is heard, or until it can be felt that the threads are properly engaged. The lens can then be screwed into the flange without any difficulty. The engagement of fine threads on a large, springy lens hood is sometimes very difficult, but it should never be forced on so that the threads are crossed. When unscrewing a shutter, there is always a temptation to use the shutter release or some other projection as a lever to get good purchase. This must be done very cautiously as they were not intended for such a purpose and may not be strong enough to stand the strain.

CARE OF LENSES. — Lenses of reputable make last indefinitely with reasonable care, but they will not stand abuse, as optical glass is softer than ordinary glass. Over-zealous cleaning and rubbing destroys the fine polish and covers the glass surface with minute scratches. It is far better to protect a lens from dust and dirt than to be forced to clean it too frequently. Do not finger the glass surfaces of a lens. Finger marks on a lens will result in fogged negatives and there may be actual corrosion of the glass from greasy fingerprints that have been left unnoticed for a long time.

Keep a cap on both ends of a lens when it is not in use. The lens must be properly protected from flying cinders when riding in a train, from dust on an automobile trip, and from sand and salt spray at the beach. Dust and sand can also work in and damage the camera and shutter mechanism, so it is always wise to keep the camera in its case when it is not actually in use. Do not store lenses where they are exposed to strong light for long periods of time. Protect them from temperature changes and extremes of heat and cold, from dampness and humidity, and from the fumes of chemicals which may cause surface oxidation. The balsam cement may be melted by the heat from hot sun or hot steam pipes. Do not focus condenser spots on the lens surfaces. If a lens is dropped or gets a sudden jar, its members may be cramped and optically strained enough to cause faulty images. When taking a lens apart, it should be held over a table covered with a thick cloth, or a bath towel, so that if any of the glasses fall, they will not be damaged. Moisture may condense on the glass, outside or inside, if a lens is brought into a warm room in cold weather, and this must be removed or it will cause flat and foggy negatives.

To clean a lens, use a soft and well-washed linen handkerchief or the special lens cleaning tissue that can be obtained for the purpose. Silk should not be used, as it is apt to become electrified and attract dust and grit. Brush off dust with a soft camel's-hair brush and then wipe the lens very lightly with a circular motion, holding the lens upside down. To remove finger marks,

breathe on the glass and then wipe with the linen or tissue. If dust or grit is not brushed off before wiping, it may be ground into the glass and destroy the fine polish of the lens. If the inner surfaces need cleaning, remove only one cell at a time, replacing it before another is taken out, to make sure that each cell is put back in the right place.

Should a lens or mount require more attention than that described above, entrust it only to the maker of the lens. Remounting and other such repairs should be done at the factory of origin, for here only are the proper tools, data and testing apparatus for accurate centering and separation adjustments that are always needed.

Never use alcohol or acids for cleaning lenses. Alcohol is a solvent of lacquers and optical blacks and the use of acids will destroy the fine polish on a lens.

UNIVERSAL LENS FORMULAS. — Almost any calculation of object or image size, ratio of enlargement or reduction, camera extension, and many other facts may be derived from the parent formula which expresses the fact that the reciprocal of the focal length equals the sum of the reciprocals of the distances of the object and the image from the lens.

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$$

The object and image distances should be taken from the admission and exit nodes of the lens, but for practical purposes, except with telephoto lenses, it is accurate enough to measure from the diaphragm of compound lenses, or from the surfaces of a single lens.

The following symbols are used in these formulas.

f the focal length of the lens.

o distance of object from lens.

i distance of image from lens (camera extension in copying, lens-easel distance when enlarging).

D distance from object to image, regardless of nodal space which is negligible compared to D .

R times of enlargement (linear size of image divided by that of object).

r times of reduction (linear size of object divided by that of image).

FOCAL LENGTH

$$f = \frac{o \times R}{R + 1} = \frac{o}{r + 1} \quad \dots \quad (1) \quad f = \frac{D \times R}{(R + 1)^2} = \frac{D \times r}{(r + 1)^2} \quad \dots \quad (3)$$

$$f = \frac{i}{R + 1} = \frac{i \times r}{r + 1} \quad \dots \quad (2) \quad f = \frac{D}{R + 2} = \frac{D}{r + 2} \text{ (approx.)} \quad \dots \quad (4)$$

$$f = \frac{o \times i}{n} \quad \dots \quad (5)$$

DISTANCE OF OBJECT FROM LENS

$$o = \frac{i}{R} = i \times r \quad \dots \quad \dots \quad \dots \quad (6) \quad o = \frac{f \times i}{i - f} \quad \dots \quad \dots \quad \dots \quad (8)$$

$$o = \frac{f}{R} + f = (r + 1) \times f \quad \dots \quad \dots \quad (7) \quad o = \frac{D}{R + 1} = \frac{r \times D}{r + 1} \quad \dots \quad \dots \quad (9)$$

DISTANCE OF IMAGE FROM LENS

$$i = o \times R = \frac{o}{r} \quad \dots \quad \dots \quad \dots \quad (10) \quad i = \frac{f \times o}{o - f} \quad \dots \quad \dots \quad \dots \quad (12)$$

$$i = (f \times R) + f = \frac{f}{r} + f \quad \dots \quad \dots \quad (11) \quad i = \frac{R \times D}{R + 1} = \frac{D}{r + 1} \quad \dots \quad \dots \quad (13)$$

OBJECT-IMAGE DISTANCE

$$D = f \times \left(R + \frac{1}{R} + 2 \right) \quad D = \frac{i \times (R + 1)}{R} = i \times (r + 1) \quad \dots \quad (17)$$

$$= f \times \left(r + \frac{1}{r} + 2 \right) \quad \dots \quad \dots \quad (14) \quad D = o \times (R + 1) = \frac{o \times (r + 1)}{r} \quad \dots \quad (18)$$

$$= \frac{f \times (R + 1)^2}{R} = \frac{f \times (r + 1)^2}{r} \quad \dots \quad (15)$$

$$= f \times (R + 2) = f \times (r + 2) \quad (16)$$

(approx.)

SCALE OF REPRODUCTION

$$R = \frac{\text{size of image}}{\text{size of object}} \quad (\text{linear})$$

$$r = \frac{\text{size of object}}{\text{size of image}} \quad (\text{linear})$$

$$R = \text{number of times of enlargement.}$$

$$r = \text{number of times of reduction.}$$

$$R = \frac{i}{o} \quad \dots \quad \dots \quad \dots \quad (19) \quad r = \frac{o}{i} \quad \dots \quad \dots \quad \dots \quad (23)$$

$$R = \frac{f}{o - f} \quad \dots \quad \dots \quad \dots \quad (20) \quad r = \frac{o - f}{f} = \frac{o}{f} - 1 \quad \dots \quad \dots \quad (24)$$

$$R = \frac{i - f}{f} \quad \dots \quad \dots \quad \dots \quad (21) \quad r = \frac{f}{i - f} \quad \dots \quad \dots \quad \dots \quad (25)$$

$$R = \frac{D - 2f}{f} \quad (\text{approx.}) \quad \dots \quad \dots \quad (22) \quad r = \frac{D - 2f}{f} \quad (\text{approx.}) \quad \dots \quad \dots \quad (26)$$

In formulas 4, 16, 22, and 26, results are sufficiently accurate for practical purposes if R or r is greater than about 9 or 10.

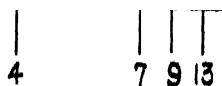
In formulas 8, 21, and 25, if o is very great relatively to f , i becomes practically equal to f , and formulas 7, 21, and 25 no longer apply.

In formula 12, if o is very great compared with f , $o - f$ practically equals o , and i therefore equals f .

Formulas 19, 20, 21, 23, 24, and 25 make it possible to calculate the size of the image of an object of known size, at a known distance, with a lens of known focal length, or, conversely, to calculate the size of an object producing an image of known size when the distance and the focal length of the lens are known.

In formula 20, if o is very great in relation to f , the latter becomes negligible and may be omitted, so that the formula will become $R = \frac{f}{o}$, and the size of the image may be said to be directly proportional to the focal length. This is not theoretically correct, but if o is at least 100 times f , the size of the image will be proportional to the distance of the object within an error of 1 per cent.

To CONSTRUCT A FOCUSING SCALE, draw a line equal in length to the equivalent focus of the lens, mark off exactly one-half, third, fourth, sixth, eighth, etc., and add 1 to each division; this will give a scale as below. Multiply each number by the focal length of the lens, and the results will be



CONSTRUCTION OF A FOCUSING SCALE

the distances in inches at which an object will be sharp if the lens is racked out to that point. To fix the scale to a camera, focus on infinity, attach a pointer to the moveable camera front, and affix the scale to the baseboard so that the line marked B , indicating infinity, will be even with this pointer, the scale extending from this mark away from the rear of the camera.

CHAPTER II

EXPOSURE

The function of a photographic negative is to record the image focused upon it by a lens, reproducing the tones of the original in inverse values by proportionate opacities in the negative. A sufficient exposure will record all the tones of the original. The action of light being cumulative, if the speed of the emulsion and the actinic value of the light reflected by the object are known, the proper duration of the exposure can be calculated.

Several methods are in vogue for determining the sensitivity of photographic emulsions. Although none of them are wholly satisfactory under all conditions, they are accurate enough to satisfy ordinary demands, and they serve as a basis for comparison of the relative speeds of different emulsions.

The negative image is formed by the action of the light which is reflected by the object that is being photographed. The intensity and actinic value of this reflected light can be measured with a fair degree of accuracy by various mechanical devices, or estimated from previous experience or by the study of charts which tabulate the value of different degrees of daylight for various latitudes, altitudes, seasons of year, and time of day.

From the product of these two factors (the speed of the emulsion and the actinic value of the reflected light) the values of which are always subject to at least some variation, is calculated an exposure time, the execution of which is usually entrusted to a photographic shutter that is never more than approximately correct in its operation. Although quite accurate exposures can be made by special timing devices used with artificial light of known and constant value, it is obvious that for the great majority of photographic exposures, which are made by daylight with ordinary shutters, there is always the possibility of considerable error even when using the most intelligent and painstaking care. Fortunately, the latitude of the emulsion is usually great enough to give a workable negative in spite of errors of the magnitude ordinarily involved. In practice, one error is often compensated for by another in the opposite direction, so that the effect of both is cancelled. If all errors happen to be cumulative, they are likely to exceed the latitude of the emulsion.

THE H & D SYSTEM.—In 1890, Dr. Ferdinand Hurter, a chemist, and Vero C. Driffield, an engineer, first published the result of their collaboration in the work of determining the sensitiveness of photographic plates. Their findings were based upon measurement of the point where the action of light

overcame the inertia of the emulsion. For many years the speed of plates and films was quite generally designated by H & D numbers. This system was satisfactory enough for emulsions in use up to about 1910, which all had very similar characteristics. Later emulsions differed so widely in their contents and in their consequent reaction to different conditions, that this system became of less value. Relative speeds could not be compared by it except under definite, standard conditions which did not prevail in ordinary working conditions.

For obtaining the H & D numbers, a negative is exposed in sections to a standard source of light, the exposures in the series increasing in the ratio of the square root of two, so that they are doubled at every second exposure. After a standard development, the resulting densities of the negative are plotted on the ordinate of the graph against the logarithms of the corresponding exposures which are plotted on the base. The base line is so placed that it eliminates the effect of fog from the calculation. Density being the logarithm of opacity, both records are in logarithms. The logarithms, instead of the actual exposure times and the actual opacity, are used only to keep the chart within reasonable size. The resulting graph takes the form of a "curve" with a straight central portion. This is the *characteristic curve* of the emulsion (see page 76). The straight-line portion of the curve, when projected to meet the base line, does this at a point which indicates the *inertia value* of the emulsion. The H & D speed number is 34 divided by this inertia value as read in meter-candle seconds. Hurter and Driffeld claimed that the point which they measured practically indicated the beginning of the period of exposure in which correct gradation is secured.

European H & D ratings are calculated so that they give about double the speed ratings obtained by the British system, and the ratings published by some manufacturers are often higher than the facts warrant, so H & D ratings cannot be used with any assurance without knowing specifically how they have been computed.

While the H & D system for speed determination has been largely superseded by other methods, the characteristic curve from which it is figured is still the basis for studying many of the other characteristics of emulsions. H & D numbers are directly proportional. That is, a speed of 1000 is double that of 500.

THE SCHEINER SYSTEM is based upon the least perceptible density on a negative which has been exposed and developed under certain standard, specified conditions. It measures the *threshold value of light*, and the principle is the same as that which was used to determine the speed of daguerreotypes. Its present form is a modification by Eder and Hecht of a system originally employed by Scheiner for astronomical purposes, in 1894. Under certain standardized conditions of light, exposure, and development, if an emulsion shows threshold value after an exposure of 1 minute at a distance of 1 meter

from the light, it has a speed of 1° Scheiner. The accuracy of this system depends to some extent upon the judgment of the observer, and it records nothing but the minimum amount of light to which an emulsion will respond, giving no indication of the amount of light necessary to record gradations correctly. Various modifications have been made in computing the Scheiner ratings, and as these have not been uniformly adopted, the European figures are now 6° higher than the American for the same speed. An increase of 3° Scheiner indicates a doubling of speed.

THE DIN SYSTEM, whose name is abbreviated from Deutsche Industrie Normen, was adopted by German manufacturers in 1934. It measures the least printable density that can be secured on a negative by an exposure of $1/20$ second to a standard light through a neutral gray scale whose densities progress by 0.1. Emulsion speeds are rated by the density of the scale at the point under which there has been obtained on the negative a density greater than 0.1 above the fog value. Thus, if this density were obtained under the scale density of 1.7, the speed of the emulsion would be written $17^\circ/10$ DIN. To obtain the data used in this system, emulsions are developed to finality, greatly exaggerating graininess and contrast, so that the results are not altogether comparable to those obtained when the same emulsion is so developed as to yield a usable negative. An increase of 3° DIN indicates an increase of 100 per cent in speed.

THE WESTON RATINGS.—The makers of exposure meters use various methods of determining the speed of emulsions, and from time to time they publish revised lists of the factors for all the more common emulsions when used with their instruments. The ratings for use with the Weston photographic exposure meter are obtained by dividing 4 by the exposure in meter-candle seconds that is required to produce a density in the negative of $1.0 \times \textit{gamma}$. The light source is standardized, and development is under specified conditions which are usually in accordance with the instructions of the manufacturer. This system therefore rates the speed of an emulsion in accordance with the amount of light necessary to produce a negative with the printing qualities usually demanded by practical workers, *if developed according to the maker's formula*. It must always be borne in mind that the practical speed of an emulsion is determined by its ability to register shadow detail, and that different processes of development vary 100 per cent in their ability to bring this out. Considerations of the necessity for obtaining fine grain, or the limitations imposed by heat and humidity in the tropics, for example, may absolutely dictate the type of developer to be used. With perfect freedom to use any desired developer, it is possible to develop slightly exposed grains of silver upon which another developer would have no effect. Obviously, different speed factors must be used to compensate for these different methods of development.

Weston speed ratings are directly proportional to each other.

COMPARISON OF SPEED RATINGS. — From the foregoing it will be seen that each of these systems is based upon the measurement of a different characteristic of the emulsion, so that there can be no exact comparison for all purposes between their ratings, but the accompanying table, worked out by Charles P. Nachod, gives the relative readings for ordinary conditions with emulsions of similar characteristics.

<i>Weston</i>	<i>H & D</i>	<i>DIN</i> (10ths)	<i>Scheiner</i>
3	150	7	14
6	300	10	17
12	600	13	20
24	1200	16	23
48	2400	19	26

In general, H & D numbers are fifty times those of Weston. American Scheiner degrees are 7 more than DIN (disregarding the latter's denominator), while European Scheiner is 13 more than DIN. Weston and H & D numbers are directly proportional to any other number in their series, while Scheiner and DIN speeds are doubled at every third step.

EXPOSURE METERS. — The various devices used to measure available light when making photographic exposures fall into three general classes — the actinometer, the extinction, and the photoelectric meters. Actinometers measure the incident light and the others the reflected light. They all, usually by a system of revolving scales, indicate the correct exposure at various lens apertures and upon emulsions of different speeds.

On account of the many variables involved, and to adjust for individual differences of lenses, shutters and meters, tests should be run under actual working conditions before accepting the reading of any meter as final. Using the meter reading as unity, make a series of exposures of the same subject under identical conditions in the ratio of $\frac{1}{4}$, $\frac{1}{2}$, 1, 2, and 4. This should be repeated on different types of subject, at different distances from the lens. When these negatives have been developed, it is easy to determine if the meter reading is correct for the apparatus and method of development in use, and if not, to know by what factor to correct it.

ACTINOMETERS. — The Watkins Bee meter and the Wynne Infallible were two of the best known among many meters of this type which measure the actinic value of the incident light by the visible darkening of a piece of sensitized paper exposed to it. The time required to darken this paper enough to match an adjacent, standard tint is known as the actinometer time, and when the scale is set so that this actinometer time is against the emulsion speed, the exposure for any stop can be read. A degree of inaccuracy was introduced by the fact that all objects do not reflect the same light equally, but in general this type of meter was quite satisfactory with the early emulsions whose characteristics were similar to those of the paper used in making

the test. Later emulsions being so different that their reactions had little in common with those of the paper, rendered this system of little use, and it was superseded by others.

EXTINCTION METERS. — In this type of meter, which measures the light reflected by an object, the light is admitted to the eye through an optical wedge until a point in its opacity is reached through which shadow detail of the scene can barely be discerned. In some instruments a translucent figure is substituted for the shadow detail of the subject, and the illumination on the figure is progressively reduced by closing an iris diaphragm until the eye can no longer distinguish it. Exposure time is then read on dials against stop opening and emulsion speed. Of this type are the Hyde, Ica Diaphot, Justophot, Bewi, Practos, Intoscope, and Leudi meters. One disadvantage of extinction meters is that they depend upon human eyesight and the power of the eye varies with the individual, but this personal equation can be learned by a few trials, and allowance made for it. This type of meter measures the visual rather than the actinic light, but most modern emulsions react very closely to visual standards, so that these meters are accurate enough for many purposes. One common source of error in their use is that the eye automatically compensates for dim light, resulting in too short an exposure for poorly lighted subjects, but this tendency can be allowed for.

PHOTOELECTRIC METERS. — A photoelectric cell is used for measuring the light in such meters as the Weston, Rhamstine, General Electric, Photoscop, Photrix, and others of this type. Although subject to some mechanical derangements, and not always reacting as the emulsion does under special conditions, this type of meter is far more accurate than any of its predecessors, as the personal element in its mechanical operation is entirely eliminated. It does require some judgment in its use, as do all exposure meters. Light is admitted to the meter from an angle which roughly corresponds to the angle covered by the lens of a camera in ordinary usage, and the photoelectric cell gives a reading which averages all the light coming through this angle. This frequently gives too high a reading to properly record shadow detail, and hence it is a common practice to incline the meter slightly towards the ground, rather than to hold it perpendicular, when metering a landscape with a bright sky. In the case of a head outlined against the sky, if a reading were taken from an angle that would include all the area desired in the picture, the greater preponderance of light from the sky would result in an exposure so short that no detail would show in the head. Under such conditions, the practice is to hold the meter so close to the head that only the light reflected from it enters the meter. The idea is to localize the reading upon important parts of a picture which might receive insufficient exposure if the reading were an average of all the light reflected from the entire included area. By advancing the meter close enough to exclude other areas, local readings can be taken upon any part of the subject so that it may receive

the most favorable exposure. Individual readings are often taken upon the highest light and the deepest shadow, especially in portraiture, to determine the brightness range of the subject.

As meters measure the light coming through the angle of the ordinary photographic lens, it is obvious that when using a wide-angle lens the meter does not measure all the light that is making the picture unless the operator moves back and reads it from a position back of the camera. When using a telephoto lens, the meter at the camera position records the light coming from too wide an angle, and it should be moved nearer the subject before taking the reading.

EXPOSURE TABLES are rather complicated as they involve the consideration of half a dozen or more factors, but when they have been tabulated upon revolving discs, as in the Burroughs Wellcome or the Kodak devices, the exposure can be calculated very quickly and conveniently and, for ordinary subjects in daylight, with considerable accuracy. The principal factors which have to be considered are the speed and color sensitivity of the emulsion, diaphragm opening, latitude, altitude, season of year, time of day, strength of light, the nature of the subject and its nearness and color. Most of these factors can be assigned standard, permanent values, leaving to the judgment of the operator only the relative strength of the light, and the nature of the subject. Each of the standard factors is assigned a definite number, and numbers are estimated for the variables. In some systems these numbers are added, and in others multiplied, to secure a final number which, by reference to a printed table, will indicate the exposure.

ESTIMATING EXPOSURE.—Exposure tables are only a convenient compilation of all the factors which have to be considered when estimating an exposure. There are so many of them that having them all tabulated prevents the possibility of carelessly overlooking one or more of them. The majority of exposures are probably made by guesswork, without mechanical aids. An observant operator who profits by his mistakes develops considerable judgment in estimating exposures, and even when meters or exposure tables are used, this judgment is valuable for detecting gross errors occasioned by faulty instruments or their incorrect use. But many operators put their sole dependence upon their own accumulated experience. They usually set themselves some simple standard of exposure for a given subject under optimum light conditions, and rate all other exposures by their relation to this.

On an emulsion of 23° Scheiner, at stop $f:8$, an average landscape, under full noon sunshine in June, in north latitude 35° to 45°, at altitudes less than 5000 feet, will require an exposure of about 1/100 second. From some such standard as this, other exposures can be estimated.

Emulsion speeds are doubled at every third degree Scheiner, and stops let in light inversely as the square of their f numbers, so these two factors are easily computed.

Lighter subjects than the average landscape which is used as a standard, require less time down to perhaps one-quarter for open sea and sky shots. Darker subjects require progressively more, up to four or more times for street scenes or dark rocks or foliage. The exposure needed for any subject decreases with its distance from the camera, and allowance has to be made for the color of the object in relation to the color sensitivity of the film.

The value of the noonday sun is progressively less, down to one-half, from June to December in northern latitudes; and inversely in southern latitudes. In midsummer the value of the light varies very little for 3 hours before or after noon. In winter this time is limited to 1 hour before or after noon, and this interval is progressive during the intervening months. Earlier or later in the day the light is progressively weaker down to about one-quarter of its noonday value. When the sun is near the horizon, its value is very weak, and changes so rapidly that exposures are hard to estimate, while the predominant yellow color of the light makes the color sensitivity of the emulsion an increasingly larger factor.

Taking the exposure for full sunlight as 1, hazy sunlight, casting only faint shadows, would require double exposure; the sun so completely overcast that no shadows are cast, would double it again; while if the whole sky were very dark it might have to be doubled yet again.

At altitudes above 5000 feet, half the exposure would be required, and above 10,000 feet, one-quarter.

The nearer one gets to the equator, the less are the seasonal differences in light, and there is a band of about 20° north and south of the equator where they are negligible. The light during the seasonal changes in extreme northern and southern latitudes varies so greatly that it can be learned only by experience or measured by a meter.

From these notes it will be seen that different subjects vary greatly in the amount of exposure that they require, and that the intensity of light varies as the time of day and season of year and as it is obscured by clouds, vapor and dust, so that it is rather a hit-or-miss proposition to estimate all these variables, but it is regularly done by many people with a large degree of success. If one establishes a satisfactory standard of exposure for a certain emulsion speed at the altitude and in the latitude where most of his work is done, the problem is simplified by leaving the intensity of the light and the nature of the subject as the principal variables which have to be estimated.

LATITUDE IN EMULSIONS.—One reason that so many exposures are successful although errors have been made in their calculation, is that there is a so-called latitude in exposure. In most instances there is no one correct exposure possible, but several. Emulsions vary in this respect, but most films can render a range of tones the intensity of which varies in the ratio of 1 to 128. Ordinary scenes present a range of no more than 1 to 30. A brief exposure that just recorded the lowest tones would utilize only one-quarter of the

capability of the emulsion. Twice, three times, or four times the exposure would still record all the tones of the original on the emulsion, and in their proper scale, the only difference being that the longer the exposure, the greater would be the over-all density of the negative. The ratio between the tones would be the same. Most scenes have a ratio of much less than 1 to 30 and the consequent "latitude" of the emulsion would be greater when recording them. In infrequent situations, the ratio is longer than 1 to 30 and there is less latitude. The exposure has to be more accurate, or some of the tones will not be recorded. Thickly-coated films, of which the double-coated are the extreme variety, can record a longer ranges of tones than thinly-coated ones can. Because such films soften definition by diffraction of light within the thickness of the emulsion, films made expressly for recording detail as sharply as possible are very thinly coated. These have a shorter scale than thick emulsions and consequently less "latitude." The scale is long enough for most purposes, but the exposure has to be accurate within narrow limits.

THE CAMERA AS AN EXPOSURE METER. — Any reflecting camera or one fitted with a groundglass, which shows the actual image made by the lens, can be used as a meter. One soon becomes accustomed to judging the intensity of the light as seen in the image at a certain stop, and can estimate the exposure required in relation to some standard that has been set up by previous experience.

Another method which is useful in dim light, as in interiors, is to cover the head with a focusing cloth and wait a few minutes until the eyes have adjusted themselves. Watching the darkest shadow detail that it is desired to record, stop the lens down gradually until this detail can barely be seen. Note the stop and find on the following table the correct exposure at $f:8$ for an emulsion speed of 23° Scheiner.

<i>Stop noted</i>	<i>Exposure at $f:8$</i>
$f:8$	64 seconds
$f:11$	32 seconds
$f:16$	16 seconds
$f:22$	8 seconds
$f:32$	4 seconds
$f:45$	2 seconds
$f:64$	1 second

FOCUSING. — On cheap "box" cameras, no provision is made for focusing because their lenses are of such short focal length and their apertures so small that the great depth of field covers their inexact requirements. These are the so-called "fixed-focus" cameras. But with longer lenses or greater apertures, focusing is one of the most important operations in making a picture. The method of focusing depends upon the type of camera. *Visual* focusing is used with reflecting cameras and those fitted with groundglass, and *scale* focusing with cameras not so equipped.

With reflecting cameras, the image is intercepted by a mirror and reflected on to a groundglass screen while the lens is racked in or out until the observed image appears sharp. The mirror should preferably be front-surfaced. If the reflection is from the back surface of the mirror, double images are formed under certain conditions of refraction. The hood should fit close to the face to exclude all light except that coming through the lens. Spectacles can be fitted into the hood to enable poor eyesight to see the image clearly at the distance from the top of the hood to the groundglass. If the face is not held close enough in the top of the hood to exclude extraneous light, the image cannot be seen clearly enough for sharp focusing. Preliminary focusing may be done with the lens wide open, as the more brilliant image thus produced is easier to focus critically, but the depth of field included can be determined only by focusing with the lens at the aperture with which the picture will be taken.

If unsharp images are secured after critical focusing with a reflecting camera, the cause is either faulty eyesight which should be corrected with spectacles, or a lack of registration between the groundglass in the hood and the focal plane. The latter may be caused by derangement of the groundglass or of the mirror, and it may be detected by comparing the focus in the hood with that at the focal plane. Many reflecting cameras have detachable groundglass panels which interchange with filmholders, which make this test very convenient. With rollfilm models the back can usually be removed and a piece of groundglass laid across the rollers for the test.

Studio cameras, view cameras, and some hand cameras are fitted with groundglass backs upon which the image is focused. The head and the groundglass should be covered with an opaque cloth to exclude all light except that which comes through the lens. This focusing cloth must be large enough to allow the eye to be at normal reading distance behind the groundglass. A focusing magnifier with magnification of two to four times, held against the groundglass, is a help in obtaining sharp focus. If the grain of the groundglass is very coarse, its transparency can be greatly improved by smearing it with vaseline or glycerin, which is especially helpful in dark interiors. If no object is well enough lighted to be seen sharply, a flashlight, a candle, or the flame of a match can be held in the plane of the object and focused upon and then removed. The most critical focusing is obtained by using the *parallax* method. A cross is scratched on the groundglass and over this is cemented with Canada balsam a piece of very thin glass, like microscope cover glass, which will make the groundglass transparent in the area so covered. A magnifying lens is adjusted to give a sharp image of the cross after the image has been focused as sharply as possible on the remaining part of the groundglass. It will then be possible to see at the same time in the area of the cemented glass, the image of the object and of the cross which is in the plane of the groundglass. If the image is focused in this plane, any displacement of

the eye will not alter the relative positions of the cross and the image. If the cross is displaced in the same direction that the eye is moved, it indicates that the camera extension is too long. If the displacement of the cross is in the opposite direction to the movement of the eye, the extension is too short.

Errors in focusing are shown by the plane of sharpest focus in the picture being either in front of or behind the object focused upon. In case of persistent error, in spite of care in focusing, the camera should be suspected and tested to see if the negative in its holder registers with the groundglass. For a visually focusing camera, focus sharply at largest aperture with a magnifier, upon some well-defined object, like a printed page, making sure that the camera is rigidly supported. The resulting negative should show if it was made in the same plane as the groundglass. Scale focusing cameras are tested by accurately measuring the distance to some prominent object and making an exposure with the scale set accordingly.

Soft focus lenses are difficult to focus because they do not, from their nature, give a sharp image. By stopping down to about $f:8$, the image is usually well enough defined to permit its being focused, after which the lens is opened up to the desired aperture for the exposure. But since the visual effect is the reason for using a soft focus lens, a satisfactory appearance of the image on the groundglass, regardless of focus, is usually all that is desired.

Visual focusing has the advantages of showing the exact amount of the picture that will be included on the negative, the exact ratio in which the size of different parts of the subject will be rendered, the exact limits of the depth of field, and the degree of unsharpness with which objects outside that field will be rendered.

Scale focusing, which is employed with most hand cameras, is accomplished by setting a pointer to the desired distance as engraved upon a scale, either upon the lens-mount in the case of helical mounting, or upon the bed of the camera. Focusing scales are not always accurate, especially upon the cheaper models of cameras, and they are liable to derangement, especially if mounted upon the bed of the camera. The focusing scale of most cameras can be tested by temporarily fixing a piece of groundglass in the focal plane, as by resting it on the rollers of a rollfilm camera with the back removed. Focus sharply upon the groundglass for both near and far measured distances and note whether or not the scale reading agrees with the visual focus. If the construction of the camera does not permit this test, focus by scale upon objects at measured distances, make exposures, and examine the resulting negatives for sharpness.

Scale focusing presupposes a knowledge of the distance from the lens to the object upon which it is desired to focus. This distance can be measured or estimated, the latter method being accurate enough for ordinary work. Most people can acquire sufficient judgment of distances with a little practice in estimating the distance of near objects and then checking and correcting

the estimate with a yardstick, and by estimating and pacing off longer distances when walking along the street.

For more accurate work, or for a person who lacks judgment of distances, the distance can be found by actual measurement or with a rangefinder. A rangefinder mechanically coupled to the lens so that it focuses it automatically as the distance is found, is a great convenience, especially upon miniature cameras, when the negatives have to be so greatly enlarged that slight errors in focusing are serious. The accuracy of a coupled rangefinder should not be taken for granted, as some of the cheaper ones are far from accurate, and even with more expensive models it will often be found that they are not exactly accurate at all distances. Coupled rangefinders should be tested by focusing them at measured distances, noting their agreement with the focusing scale, and by making exposures, or by the use of a groundglass as noted above, seeing if the negative is really sharp at near, middle, and far distances.

The table of hyperfocal distances on page 14 is a great help when using scale-focusing cameras. Having found the distance of the nearest and the farthest objects that must be sharp in the picture, a glance at the tables will show the distance setting for the lens, and the stop to be used.

RESOLVING POWER.—The sharpness of the image depends upon the accuracy of the adjustments of the camera, the care used in focusing, and the resolving power of the lens and of the photographic emulsion. The lens can usually resolve finer detail than can be recorded by the emulsion. The films in most common use will resolve from 45 to 55 lines per millimeter when photographing a test chart which has lines alternated with spaces of the same width, which is the standard method of testing. Special films have resolving power as high as 100 or more lines per millimeter. The resolving power of a film depends upon the nature of the emulsion, its thickness (being greater in thin emulsions), and also upon the contrast of the subject, the exposure, and the kind and degree of development. Resolution falls off with either under- or overexposure, which indicates the necessity for correct exposure of miniature negatives. Fine-grain developers increase the resolving power of films from 5 to 10 lines per millimeter.

TELEPHOTO EXPOSURES.—Telephoto lenses with fixed separation and a definite degree of magnification are used exactly like other photographic lenses. With the older type, which has adjustable separation between a positive lens and a telephoto attachment negative lens, so that different degrees of magnification can be made, the exposure depends upon the degree of magnification. This can usually be read off directly on the mounting, or it can be found by comparing the image size that is obtained by the regular lens with the size obtained by that lens with the telephoto attachment added. The normal exposure for any stop, multiplied by the square of the magnification, gives the telephoto exposure. If the normal exposure at $f:16$ is $1/100$ second,

the exposure with a four times magnification when using the same actual stop, would be $4 \times 4 \times 1/100$, or approximately $\frac{1}{6}$ second.

EXPOSURES AT NIGHT. — No definite rule can be given for exposures out of doors at night, as the illumination varies enormously under the influence of the nearness, number, and intensity of street lights, illuminated signs, and lighted windows. Panchromatic emulsions are comparatively much faster than orthochromatic to these lights. Snow on the ground, or wet pavements, or the moon near its full, halve the regular exposure. From the nature of most subjects taken at night, the definition need not be critically sharp, so larger apertures can be used than would be possible for the same subjects in daylight. At $f:2$, with panchromatic films of 23° Scheiner, or faster, it is possible to make snapshots at $1/25$ second on well-lighted streets. Exposures with less illumination or slower lenses or emulsions may well run into minutes. Intermittent exposures are often given scenes which require long exposure which is likely to be disturbed by infrequently passing traffic. When vehicles or pedestrians cross the field of view, the exposure is interrupted by closing the shutter or capping the lens. Successive exposures are thus given until their sum aggregates the desired time.

PINHOLE EXPOSURES. — When photographic images are formed by pinholes instead of lenses, the strength of the light and the speed of the emulsion are ascertained as for exposures with a lens. The f value is found by measuring the actual distance from the pinhole to the negative and dividing this by the diameter of the aperture. In common practice "pin" holes are made by piercing thin metal or paper with needles and the diameter of the hole can be found closely enough by laying a number of needles of the size that made the hole side by side to the width of an inch, and counting them. The sizes of the needles most commonly used are

No. 8	1/45 inch
No. 10	1/55 inch
No. 11	1/65 inch
No. 12	1/75 inch

W. L. F. Wastell, in *The Modern Encyclopedia of Photography*, points out that if a pinhole were located 1 inch from the negative, its diameter would be its f number, and that exposures can be calculated for this number and then multiplied by the square of the distance between pinhole and negative. For example, if the diameter of a pinhole is $1/45$ inch and the exposure for $f:45$ is found to be $\frac{1}{2}$ second, if the distance from pinhole to negative is 6 inches, then $\frac{1}{2} \times 6^2 = 18$ seconds. Authorities differ as to whether the f values as used with lenses hold good when using pinholes, some claiming that they do, others that relatively less exposure should be given, and others that more should be given. But they will at least serve as a basis for a trial exposure

from which the worker can set his own standard. As the illumination towards the margins of the negative falls off quite noticeably when using pinholes, a rather full exposure is desirable.

PHOTOGRAPHING LIGHTNING. — The camera is focused upon infinity, fixed upon a firm support, and pointed in the direction in which the flashes occur. The shutter is left open until a flash occurs, or it may be left open until several flashes have been recorded upon the same negative. The light is so intense that emulsion speeds and aperture settings are unimportant. If the shutter is left open long enough, some landscape detail can be recorded, which may add to the attractiveness of the picture.

MOONLIGHT EXPOSURES. — To record tonal differences or any detail in a landscape illuminated only by the moon, requires an exposure so long that the moon itself cannot be included in the same picture. Not only would it be so hopelessly overexposed that no detail could be recorded on its surface, but its circular shape would become an ellipse on account of its movement. Moonlight exposures vary greatly, depending upon the strength of the light, and the effect desired, and can be best learned by trial and error. A basis for trial might be 5 minutes for an open landscape, at $f:8$, on an emulsion of 23° Scheiner, under a full moon. The half moon gives only one-tenth as much light as the full moon. In photographing the surface of the moon itself, not more than 1 second exposure can be given without showing motion, if the result is to be enlarged. The image moves a distance equal to its own diameter every 2 minutes. The size of the image will be approximately $1/100$ of the focal length of the taking lens, so the resulting image will be disappointingly small unless lenses of long focal length are used. Moonlight pictures showing a landscape and including the moon, are sometimes made by combination exposures. After a sufficient exposure for the landscape with the camera so placed that the moon itself is not included, the camera is tilted so that the moon comes at a predetermined position in the picture, and another exposure given for it. In such pictures, of course, shadows and reflections will not appear in their true relation to the position of the moon.

According to Joseph Guild in *AMERICAN PHOTOGRAPHY*, April 1936, the only time when the moon and a landscape can be photographed simultaneously is when both the sun and the full moon are in the sky at the same time, near opposite horizons. The picture must be taken when the moon, sky, and landscape have arrived at their best relative brilliancy. If a minimum exposure is given for the landscape it will be the darkest part of the picture, while the sky will be dark enough to afford good contrast to the moon. The size of the moon is so habitually exaggerated by artists that it looks unnatural when correctly rendered. The best that the photographer can do is to get as large an image as possible and then enlarge it to a size satisfactory for his picture space, regardless of the small angle of the landscape included.

ARTIFICIAL LIGHTING.—Successful exposures, if of sufficient duration, can be made by any form of artificial light, but electric light offers such advantages in availability, portability, and economy that it is the one most frequently used. The electric arc quite closely resembles daylight in its quality and is used for special purposes where great intensity of concentrated light is needed, but it is too hot and too cumbersome for general use. Mazda lamps are used in a great variety of sizes. The naked light is usually too harsh for ordinary use, so it is softened by the interposition of groundglass, chiffon, silk, or some other diffusing medium, or preferably by using flashed opal or groundglass in the construction of the bulb itself. Greater intensity is secured by using the so-called Photoflood lamps, overrun lamps whose filaments are wound for a lower voltage than the current upon which they are usually run, resulting in a great over-load, giving intense brilliancy for the life of the lamp, which is only a few hours. The efficiency of all Mazda lamps diminishes constantly with use, until near the end of the life of the lamp it is usually not more than one-third as great as when new. The speed of deterioration is especially marked with Photoflood lamps because of the shortness of their lives. On account of this constant deterioration, and because lamps are made in such a great variety of sizes and types which are continually being changed, exposure tables for their use are not of much permanent value. Exposure times are best determined by the use of a meter, or by trial and error, at least until the operator has acquired some experience with a particular type of lighting. After a little experience, standard exposures are readily established, the only variables being the age of the lamps and their distance from the subject. The intensity varies as the square of the distance and is greatly increased by the use of parabolic reflectors, and by light surroundings. A modified form of stroboscopic light (see page 51), giving spark exposures of about $1/30,000$ second, can be synchronized to ordinary camera shutters, and used with emulsions as slow as the commercial type. The light is useful for studio pictures of moving objects, especially when making color separations.

Almost all emulsions have a lower speed rating to artificial light than to daylight, panchromatic emulsions losing less speed than other types.

FLASHPOWDERS vary so much in strength that the maker's recommendation for the amount needed should be followed. Average charges for emulsions with speed ratings of 17° to 20° Scheiner, at $f:8$, would be:

6 feet	15 grains
12 feet	40 grains
24 feet	105 grains
36 feet	180 grains

The duration of the flash depends upon the amount of powder used, and also upon whether it is heaped up or spread out thin. Fifteen grains with ordinary concentration burns for 0.03 second; 30 grains for 0.05 second; 45 grains for 0.07 second; and larger amounts in about this ratio. If the powder is

heaped up, the duration of the flash is decreased by about one-third, while if it is spread out, the time of burning is about doubled.

Flashpowder is a very dangerous explosive, and many serious accidents have occurred through its accidental discharge, or firing it in a container which has a confining action upon the explosion. It should always be used in an open pan, and a minute or more should elapse before examining a misfire, as the powder under some conditions hangs fire. Unexploded powder should be dumped out of the pan before examining a misfire.

PHOTOFLASH LAMPS. — Although considerably more expensive than flashpowder, flashlamps, which made their appearance in 1930, have generally superseded it in use because they are safer, more convenient, more consistent in results, and because they eliminate all noise, dust, and sudden glare. The power of the lamp varies with the size and construction of various makes, and as the models are frequently changed and improved, no suggestion of their speed would have any permanent value, but reliable information can be had from the manufacturers. In general it is several hundred times that of Photoflood bulbs. The total duration of the flash varies with different types from 1/16 to 1/60 second, but the peak of the actinism is spread more in some types than in others, which is an important consideration when synchronizing the flash with high shutter speeds. Lamps with the longest flashes are necessary when synchronized to focal-plane shutters so that the duration of the flash will be as long as the time necessary for the opening in the shutter to travel completely across the negative.

PHOTOGRAPHY OF MOVING OBJECTS. — The exposure must sometimes be a compromise, as when the maximum shutter speed that will give a sufficiently exposed negative is too slow to stop the motion. If the discrepancy is too great, a satisfactory picture is impossible. Some help is obtained by the fact that while needle-sharp definition is necessary for record purposes, it often destroys the illusion of motion, and for pictorial purposes, a slight blurring of the image often conveys the appearance more realistically. The worker must set his own standards of sharpness, depending upon the effect desired.

The shutter speed required depends upon the rate of movement of the image at the focal plane of the camera. The speed of the object is usually most conveniently estimated in miles per hour, which must be reduced to inches per second to be comparable to discs of confusion which are computed in fractions of an inch, and shutter speeds which are computed in fractions of a second. The image moves in the same ratio to the object as their relative sizes, so that at twice the distance, double the exposure can be given with no more linear displacement. The size of an image is found by the formula

$$\frac{(\text{object size}) \times (\text{focal length of lens})}{(\text{distance of object}) - (\text{focal length of lens})} = \text{size of image}$$

Thus, for photographing with a 6-inch lens, a 6-foot man, walking at right angles to the camera, at 3 miles per hour, at a distance of 50 feet

$$\frac{72 \times 6}{600 - 6} = \frac{432}{594} = 0.727 \text{ inch} = \text{size of image}$$

The ratio between image and object is 1 to 99. As the object moves 52.8 inches per second, the image will move 0.53 inch per second. Roughly, the object would be displaced about 50 inches in 1 second and the image would be displaced about one-half inch. In 1/53 second it would be displaced 1/100 inch, and that exposure would give acceptable sharpness for the body of the man for a contact print. But allowance must be made for the fact that while the whole body is progressing at 3 miles per hour, the feet are alternately stationary and moving, and that their movement is thus about double that of the body as a whole. This holds true of the individual parts of many other objects in motion, as, for example, the legs of a horse and the hocks, the motion of which is even faster than that of the legs. Allowance must also be made for the decrease in sharpness by any contemplated amount of enlargement from the negative.

For quick calculation the displacement of the object can be closely approximated by multiplying its speed in miles per hour by 20, and this result by the shutter speed in seconds.

$$(\text{Object speed in mph}) \times (20) \times (\text{Shutter speed}) = \text{Object displacement}$$

In the previous illustration this would work out

$$3 \times 20 \times \frac{1}{50} = \frac{60}{50} = 1.20 \text{ inches}$$

as against the previous more careful calculation of 1.06 inches.

The Thornton-Pickard Co. suggested the following short-cut for quick calculation of the shutter speed.

$$\frac{\text{Distance of object in inches}}{(\text{Speed per hour in yards}) \times (\text{focal length of lens in inches})}$$

Applying this to the former problem

$$\frac{600}{5280 \times 6} = \frac{600}{31,680} = \frac{1}{53} \text{ second}$$

The above calculations assume that the action is taking place at right angles to the axis of the lens. If the movement is directly towards the lens, or directly away from it, the displacement of the image is largely confined to its changing size, and one-third the shutter speed can be used. At an angle of

45°, two-thirds as much shutter speed can be used as at an angle of 90°, and the speed for intermediate angles can be estimated from these.

As the actual displacement of the image depends upon its relative size, which is determined by the focal length of the lens and the distance of the object, it is convenient to combine two of the factors by estimating distances in multiples of the focal length of the lens, as has been done in the following table, which is calculated for a disc of confusion of 1/250 inch.

MAXIMUM EXPOSURE IN FRACTIONS OF A SECOND FOR MOVING
OBJECTS

<i>Objects moving at right angles to camera</i>	<i>Miles per hour</i>	<i>Distance from camera in focal lengths</i>		
		<i>50</i>	<i>100</i>	<i>500</i>
Man walking	3	1/300	1/150	1/30
Horse walking	4	1/400	1/200	1/40
Horse trotting	9	1/1000	1/500	1/100
Boats and vehicles	10	1/900	1/450	1/90
Horse running	20	1/2000	1/1000	1/200
Horse racing	30	1/3000	1/1500	1/300
Trains and automobiles	30	1/2500	1/1250	1/250
Trains and automobiles	60	1/5000	1/2500	1/500
Games and not very active sports		1/1000	1/500	1/100
Foot races, jumping, and active sports		1/2000	1/1000	1/200
Diving		1/1000	1/500	1/100

Shutters vary greatly in the accuracy of their indicated speeds, so that only by trial and error can the efficiency of any given shutter in stopping motion at any indicated speed be determined, but the above list will serve for trial.

Pictures from a moving vehicle can be taken at the same speed that would be used in photographing the vehicle itself from a fixed position at the same distance. When photographing objects moving so fast that they cannot be stopped with any available shutter speeds, the exposure is sometimes made while swinging the camera in the same direction that the object is moving. With a little practice, this results in a sufficiently sharp image of the moving object, with the background blurred, and the result is often very realistic.

Airplanes in flight, if photographed from the ground, are usually at an infinite distance, measured in focal lengths, and the image is so small that speeds of 200 mph can be stopped by an exposure of 1/100 second. Photographs from a plane are usually made at lesser altitudes, and 1/250 second is usually considered the slowest exposure that can be made with assurance, although if the angle is not too great, successful shots can sometimes be made as slow as 1/100 second. A yellow filter to cut the haze is usually needed. Shots through the glass window of a plane need double the exposure. If the camera is in contact with any part of the plane while the exposure is being made, vibration will be transmitted to the camera, resulting in an unsharp image. There is usually such an abundance of light in the air that correct exposure times are much faster than the slowest time that will stop motion.

DISCRETION IN EXPOSURE. — For several generations the first rule of photography was to expose for the shadows and let the highlights take care of themselves. As a matter of fact, what was done was to make the exposure favor the shadows, and development the highlights. Development was stopped when the overexposed shadows had sufficient density, before the highlights were blocked. This treatment shortened the scale, an advantage with contrasty subjects, and it emphasized the shadows.

A later school of thought advocated the opposite treatment of exposing for the highlights and developing to gamma infinity. The short exposure prevented the highlights from blocking, while the extreme development brought out the shadow detail. This method is particularly suitable for flatly lighted subjects, as it lengthens the scale and emphasizes the highlights.

Both schools have put the emphasis where they thought it most needed. Neither method is of universal value, but only as it happens to be appropriate to the contrast of the subject. An average exposure with normal development will render an average scene much as the eye sees it, but if either end of the scale seems more important than the other, the exposure and the development can be adjusted to favor it.

For ordinary work, that will not be subjected to excessive enlargement, it is well to err on the side of overexposure, which the latitude of the emulsion will easily take care of while at the same time providing a margin of safety that will assure detail in the shadows in spite of possible errors in estimating the exposure, or inaccurate working of shutters. But for work that has to be enlarged fifteen or more diameters, it is customary to give the minimum correct exposure, which results in thinner negatives which are less liable to show grain. When it is desired to record the utmost in fine detail, a minimum exposure is indicated, to prevent as far as possible the spreading and refraction of light rays in the thickness of the emulsion, and also to utilize the best resolving power of the lens, as mentioned on page 12.

VIBRATION DURING EXPOSURE. — Any movement of the camera during exposure causes an actual displacement of the image, resulting in unsharp negatives if the total movement in the elapsed time of the exposure is greater than the acceptable disc of confusion. Individuals vary greatly in the length of time they can hold a camera steady. Few people have any trouble, if ordinary care is used, with exposures of less than $1/50$ second. At slower shutter speeds, the weight of the camera is a factor, as heavier cameras are easier to hold steadily. With miniature cameras, extra care should be used when making any exposure less than $1/60$ second. Stand squarely upon both feet and hold the camera firmly but with moderate pressure against the body. Have the body relaxed rather than tensed. Draw a full breath, exhale slightly, and then hold the breath at the instant of exposure. Cameras can often be held rigidly against a tree, fence, or building or some other solid support while making slow exposures. A strap around the neck against which

the camera can be strained, or a chain or cord from the tripod socket to the ground, held taut by the foot, are great helps. In heavy winds, brace the body against some firm object, or sit down and hold the camera against the knee.

EFFICIENCY OF SHUTTERS. — The accuracy of a shutter speed is usually computed from the time it is open enough to let in any light, until it is completely closed. Within the time of operation, there is considerable difference in the amount of light that various shutters will allow to pass. It is generally considered that very efficient focal-plane shutters will admit about one-third more light in a given time than will shutters of the blade or diaphragm type. Diaphragm shutters admit, as soon as they begin to open, a small beam of light which rapidly expands to full volume as the iris expands, and then decreases again until the shutter is fully closed, so that for an appreciable part of the exposure the full opening of the diaphragm is not utilized.

FOCAL-PLANE SHUTTERS. — With a focal-plane shutter the exposure is made in sections by the light coming through a slit which travels across the face of the negative. Theoretically this should always give rise to distortion of moving objects, but in practice the effect is usually negligible, especially if the object is of irregular shape, like an animal or a person. Distortion is most often noticeable on the wheels of very rapidly moving automobiles as the circles of the wheels have a well-known shape from which any variation is obvious. If the shutter is traveling in the same direction as the image of the wheel or at right angles to it, it will appear elongated, and if in the opposite direction, contracted. This distortion is noticeable only when one has the combination of extreme speed and a near viewpoint. The curtain of most focal-plane shutters accelerates during operation so that at the end of its travel it is moving two or three times as fast as at the beginning. This means that the negative will be unevenly exposed. If the curtain moves vertically the foreground in a landscape will receive more exposure than the sky, which may be advantageous. But if the curtain moves horizontally, one side of the negative will receive more exposure than the other, and this is sometimes noticeable enough to be troublesome.

FILTERS. — Filters are either *selective*, or *corrective*. Selective filters cut sharply, as only certain definite wavelengths of light can pass through them. They are used in science when it is desired to photograph with only one color of light. The Wratten filters A, B, and C-5, used for making color separation negatives, are selective and each one passes most of the light of its own color, and practically excludes all other light. Wratten filter 88A transmits only infra-red and cuts out all visible light. Other selective filters handle different colors.

Corrective filters are used when there is an unwanted preponderance of some color in the light, or when the photographic emulsion is unduly sensitive to some particular color. They are not sharp-cutting as they let through light

of all colors, but in varying amount, admitting more of their own and neighboring colors and restraining their opposites, thus roughly balancing the light better for photographic purposes. Even highly color-corrected emulsions are usually unduly sensitive to blue. While practically all light sources available for photography, with the exception of mercury vapor, contain all the colors of the spectrum and some ultra-violet and infra-red, these colors occur in different proportions. Sunlight and arc-light are strongest in ultra-violet. Blue daylight (light reflected from blue sky) and arc-light are strongest in blue. Mazda light (including Photoflood and Photoflash in lesser degree) is strongest in red, and noticeably deficient in blue. Objects under a preponderance of light of their own color receive a disproportionate amount of exposure and appear unnaturally light in the final print. Corrective filters are used to counteract this tendency. The strength of color needed in a filter to assure full correction depends upon how much the light is out of balance and to what degree the emulsion has been corrected for color, even panchromatic emulsions varying in this respect. Exposure must be increased when using a filter, as they all hold back part of the light, including some of their own color. The amount that the exposure must be increased is figured as a factor by which the correct exposure without a filter must be multiplied. This factor is correct only for the emulsion for which it has been computed, and for cases where extreme accuracy is necessary the manufacturers compute and publish the factors for each batch of emulsion. Different brands of color-blind, orthochromatic, and even panchromatic emulsions vary greatly in their relative sensitivity to different parts of the spectrum, and require different factors for the same filter. Filter factors for the same emulsion are different for daylight and artificial light. The designation of a filter as so many times, as $2\times$ or $5\times$, is perfectly meaningless unless it is stated for some particular type of emulsion, and whether for daylight or artificial light.

To ascertain the approximate exposure for any given filter it is often placed over a photoelectric meter before taking the reading, but this is not even approximately correct except with panchromatic emulsions having sensitivity similar to that of the eye.

Because using a filter strong enough to give full correction slows down the exposure to what are sometimes troublesome lengths, the matter is often compromised by using a lighter filter which gives only partial correction but permits a faster exposure. On the other extreme, overcorrection is often deliberately used to obtain unusual and spectacular effects, like the use of the Wratten G filter or its equivalent for darkening skies, or the A filter for making them absolutely black. Used in this way, these filters falsify all colors, notably by rendering green foliage as very light, or even white.

Sky-filters, which are graduated from deep yellow at the top to clear glass at the center, are really efficient only when placed at not less than the focal length of the lens in front of it, which is impractical.

Filter Usage Table. — Laurence Dutton in *THE AMERICAN ANNUAL OF PHOTOGRAPHY*, 1939, has compiled the accompanying table of filter usage for some of the Wratten filters, which explains the purpose of most of the filters in common use.

COLORLESS FILTER

#1	Corrective	Ultra-violet absorbing. Haze cutting without other effect.
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YELLOW FILTERS

K-1	#6	Corrective	Absorbs part of ultra-violet and blue. For partial correction, with minimum loss of speed.
K-2	#8	Corrective	Absorbs all ultra-violet and part of blue. Gives full correction to Class B Pan in daylight, partial correction to Super Pan.
K-3	#9	Corrective	Absorbs more blue. Over-corrects modern emulsions.
G	#15	Contrast	Absorbs all blue and part of green, producing exposures by yellow and red only. Used for picking up blue as black. Some pictorialists like it for landscapes.

RED FILTERS

A	#25	Selective	Standard tri-color red. Used for black skies, for infra-red, outdoors, and for picking up red as white.
F	#29	Selective	Stronger than A. Used for color separation from transparencies and for picking up light red.
	#88A	Selective	Infra-red. Cuts out all visible colors but transmits infra-red. Used with infra-red emulsions in studio.
	#31		Minus Green 1. Used to pick up green as black while other colors come out light.
	#32		Minus Green 3. Stronger than #31.

GREEN FILTERS

X-1	#11	Corrective	Absorbs ultra-violet, part of blue and part of red. Gives full correction with Super Pan in daylight; Class B pan in Mazda light.
X-2	#13	Corrective	Absorption similar to X-1 but stronger. Gives full correction with Super Pan in Mazda light.
B	#58	Selective	Standard tri-color green. Used for picking up green as white, other colors as black.
N	#61	Selective	Stronger than B. Used for color separation from transparencies and for separating weak colors.

BLUE FILTERS

C-5	#47	Selective	Standard tri-color blue. Used for picking up blue as white, other colors as black. Makes any emulsion color-blind.
C-4	#49	Selective	Stronger than C-5. Used for color separation from transparencies.
L	#50	Selective	Stronger than C-4. Used for the same purpose and for black and white separation of weak colors.
	#43		Minus Red 2. Used to pick up red as black, while other colors come out light.
	#44		Minus Red 4. Stronger than #43.

Filters are furnished in three forms: plain gelatin film; cemented in "B" glass; and cemented in "A" glass. Gelatin filters are quite as efficient as the others and are very inexpensive, but they are quite fragile and rather inconvenient to handle. The B filters, which cost more, are cemented between

sheets of plane-parallel glass which makes them much more convenient to handle and less liable to damage. This glass is surfaced with sufficient accuracy for general photographic work, and for most scientific purposes. The A filters, which are required for the greatest accuracy with long focus lenses of large aperture, are cemented between hand-surfaced optical flats and necessarily cost several times as much as the B filters.

Gelatin filters are easily subject to damage, and when not in use should be placed in clean paper between the leaves of a book to keep them flat and dry. Moisture tends to cloud gelatin film filters and they should be handled only by their extreme edges to avoid fingerprints upon them. Cemented filters should be treated with the same care as lenses, and never allowed to become damp or dirty. They should never be washed with water because if water comes in contact with the gelatin at the edges of the filter it will swell and separate the glasses and impair the definition. They may be cleaned by breathing on them and polishing with a cloth, or in extreme cases by gently rubbing with a piece of fine tissue paper moistened with denatured alcohol. The tissue should never be so wet that the alcohol will spread over the edges of the filter, as it is a solvent of the balsam with which filters are cemented.

Ultra-Violet and Æsculin Filters.—Æsculin (esculin) filters are glass cells containing a 1 to 500 solution of an extract from the bark of the horse chestnut, used to absorb ultra-violet rays. In process work some white pigments (notably Chinese white) reproduce as gray unless an æsculin filter is used. For general use æsculin filters have been largely supplanted by ultra-violet (U.V.) filters of dyed gelatin like the Wratten No. 1. These are particularly useful when photographing at high altitudes, especially under a winter sun, because the predominant ultra-violet rays are so much shorter than the visual rays that they are not focused upon the same plane unless intercepted by a U.V. filter.

POLARIZING SCREENS.—Under normal conditions, light vibrates in every direction at right angles to its pathway, but under certain conditions it can be polarized so that there remain vibrations in one direction only. The light from a blue sky at right angles to the sun's rays and the light reflected from a non-metallic surface are polarized. By the use of commercially obtainable screens, light can be polarized for photographic use. With one polarizer, used over the lens, it is possible to decrease at will the luminosity of the sky without affecting the brilliance of other parts of the landscape, whose values will not be distorted as they are when the sky is corrected by the use of a filter. By photographing through a polarizer at an angle of about 35° , reflections on all non-metallic surfaces can be reduced to such an extent that the texture of the surface is shown, or that an object behind the reflecting surface, as in a showcase or store window or a picture under glass, can be seen. The exposure is usually about four times normal on account of the light lost by polarization and the color of the screen.

When a polarizing screen is placed over the light source as well as over the lens, reflections from any surface, including metals, can be decreased at will, and from any angle. Polarized light is controlled by rotating the screens, and its effect can be watched upon the groundglass of the camera and the screens rotated until the result is satisfactory. When using a camera not equipped with a groundglass, the screen can be held in front of the eye in line with the lens, and rotated until the desired effect is secured, and the screen then placed over the lens at the same degree of rotation. Two polarizing screens, one in front of the other on the lens, can be used as a neutral density filter. When the planes of the screens are at right angles to each other, all light is occulted, but by rotating them, more and more light is admitted until, when the planes are parallel, all the light polarized by the first screen is passed freely by the second. In this way, any degree of occultation can be secured.

SPARK EXPOSURES (*Stroboscopic*) of extremely rapid motion are taken without shutters by the light of electric sparks whose duration can be regulated down to about $1/3,000,000$ second. The spark is obtained by the discharge of a condenser at voltages from 1000 upwards, and the use of electrodes of metals which emit intense light in the wavelengths to which the emulsion has the greatest sensitivity, permits sufficient exposures. Some photographs are taken in the ordinary way by reflected light through a lens, and some by using the spark behind the object, so that a shadow photograph is obtained. The light is placed so far from the negative that practically parallel light is obtained and the shadow picture is made without the use of a lens. This method is used for pictures of projectiles in flight, and the motions of gases and pressure waves following explosions are also shown as shadows. As the interval during which such pictures must be taken may be anywhere from $1/5000$ to $1/100,000$ of a second, it is necessary for the moving object itself to set off the spark. When photographing bullets, the sound wave or the gases operate a sensitive interrupter which opens an electrical circuit operating a magnetic release which throws the switch in the condenser circuit. When photographing exploding gases, two explosions are used, one traveling enough faster than the other to operate the spark device at the time the other has arrived in front of the negative. For other uses, see page 42.

INFRA-RED. — Plates and film sensitive to infra-red radiations are used for scientific purposes, but most commonly for distant landscape photography, as they will reproduce detail that is ordinarily obscured by atmospheric haze. They may be used with red filters which absorb all the blue light, but transmit the visible red, or with special filters which absorb all visible light.

As exposure meters measure only visible radiations and there is no constant ratio between visible and infra-red radiations, meters cannot be used to determine daylight exposures with infra-red emulsions. As a general guide, an open landscape under summer sunlight will require an exposure of about $1/25$ second at $f:5.6$ when using Kodak Infra-red film with either Wratten

A or G filters. If the Wratten 70 filter, which cuts out all visible red light, is used, the exposure will be double.

Infra-red film must be handled in total darkness as most safelights transmit enough infra-red radiations to fog the film.

Infra-red light is of such long wavelength that it does not focus upon the same plane as visible rays. The general practice is to increase the camera extension $1/200$ of the focal length of the lens after focusing visually. On some miniature cameras a special mark is placed upon the focusing scale to indicate the extension for infra-red at infinity.

CHAPTER III

DEVELOPMENT

When a photographic emulsion is exposed to light, an invisible, "latent" image is formed in the silver halides (bromide, iodide, or chloride of silver) which the emulsion contains. The nature of this action is somewhat obscure, but it is probably physical rather than chemical. Photography depends upon the fact that the silver halides in which this action has occurred can be changed by suitable reducing agents to metallic silver, making the image visible. This is the process of development. Many reducing agents would convert all the silver halides to metallic silver regardless of the action of light upon them, thus burying the latent image. The reducers that are useful to photography have a selective action, attacking first the silver halides that have been acted upon by light, and in proportion to the strength of the light-action upon them. There are many such reducing agents, most of them by-products of coal tar. They are used in solution with other ingredients which play important parts in the process of development. All developing agents must oxidize readily, and an alkali, usually sodium carbonate, is generally added to assist in this function. The reducer with the alkali alone would oxidize immediately in the solution, before it could penetrate the emulsion to do its work, but for the action of a preservative, usually sodium sulphite, which retards this action until the solution is brought into contact with the ingredients of the emulsion. An energetic developer is liable to deposit a small amount of silver even where no light-action has taken place, resulting in what is known as chemical fog. To prevent this, potassium bromide is added as a restrainer. Some bromide is present in the emulsion and is dissolved out into the developer, but not usually in sufficient quantity to prevent fog, so a small additional amount is supplied.

The following are the most commonly used developers, with standard formulas for their use. *Anhydrous* (sometimes called *desiccated*) sulphite and carbonate are intended in the formulas in this book unless another form is specifically mentioned. Should it be necessary to convert them, 1 part of anhydrous (desiccated) sodium sulphite practically equals 2 parts of the crystals. One part of anhydrous sodium carbonate equals 1.17 parts of the monohydrated or 3 parts of the crystal. In all formulas, chemicals should be mixed in the order given. Development times are seldom given with these formulas, and then only as a general guide, because the time varies greatly for individual needs and for different emulsions.

AMIDOL, Diaminophenol, Dianol, $C_6H_3(OH)(NH_2, HCl)_2$, introduced by Bogisch in 1891, is one of the few reducing agents so active that it can be used

in combination with sodium sulphite alone, without any alkali. This solution oxidizes rapidly and must be prepared shortly before use. It can be kept up to a day or two by the addition of acid, but this very greatly slows down the action of the developer, which then begins in the lowest layers of the emulsion after infiltration through the upper layers has freed it from the excess of acid.

TYPICAL AMIDOL FORMULA

Sodium sulphite	240 gr.	28 g
Amidol	55 gr.	6 g
Potassium bromide	12 gr.	1.4 g
Water to make	20 oz.	1000 cc

Potassium metabisulphite is the acid most commonly used with amidol, and it makes a very suitable developer for reducing the contrast of negatives of harshly lighted subjects, or for developing greatly overexposed negatives.

ACID AMIDOL

Sodium sulphite	250 gr.	13 g
Potassium metabisulphite	100 gr.	5.2 g
Potassium bromide	10 gr.	0.5 g
Amidol	50 gr.	2.6 g
Water to make	40 oz.	1000 cc

SOFT WORKING AMIDOL (Balagny)

Amidol	90 gr.	10 g
Sodium bisulphite lye, 35° Bé.	4½ dr.	30 cc
Sodium sulphite	50-70 gr.	6-8 g
Water to make	20 oz.	1000 cc

Development is very slow, running from 2 to 12 hours, depending upon the kind of emulsion and the degree of contrast wanted.

CHLORHYDROQUINONE, Adurol, Chlorquinol, $C_6H_3Cl(OH)_2$ or $C_6H_3Br(OH)_2$ is closely akin to hydroquinone but preferred by some workers because it is faster working, less sensitive to cold, and keeps longer. It is most often used in combination with some other reducing agent, but may be used alone.

CHLORHYDROQUINONE

Sodium sulphite	1750 gr.	200 g
Potassium carbonate	2600 gr.	300 g
Water to make	20 oz.	1000 cc

When dissolved add:

Chlorhydroquinone	440 gr.	50 g
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This makes a concentrated stock solution which is diluted with 3 or more parts of water for developing negatives.

Metol-chlorhydroquinone is sometimes used in place of metol-hydroquinone when it is necessary to work at low temperatures. In any metol-hydroquinone developer, 1.3 parts of chlorhydroquinone may be substituted for each part of hydroquinone.

GLYCIN, Athenon, Glyconol, Iconyl, Kodurol, $C_6H_4(OH)(NH\cdot CH_2CO\cdot OH)$, introduced by Bogisch in 1891, is a clean-working fine-grain developer which does not readily oxidize either in air or in carbonated solutions, even when greatly diluted. This makes it very convenient for machine development of motion-picture or other film in long strips. It is most often used in combination with other developers. It is practically insoluble in cold water, but may be dissolved in a solution of sodium sulphite, although it will not be completely dissolved until the carbonate is added. Potassium carbonate is usually preferred to sodium carbonate for use with glycin because it permits the use of more concentrated solutions. "Huebl paste" as given below, is a standard formula. .

GLYCIN DEVELOPER

Sodium sulphite	1450 gr.	165 g
Hot water (130° F.)	10 oz.	500 cc
Glycin	1200 gr.	135 g

Mix well, and add gradually:

Potassium carbonate	5500 gr.	625 g
Water to make	20 oz.	1000 cc

Shake well before use. The normal dilution is 1 to 12 for tray development, but less dilution may be used for obtaining more contrasty negatives. For tank development, this paste may be diluted up to 50 volumes of water.

HYDROQUINONE, Hydrochinon, Hydrokinone, Quinol, $C_6H_4(OH)_2$, introduced by Abney in 1880, is capable of producing great density in a negative while retaining perfect transparency in unexposed areas, which makes it an ideal developer for subjects requiring extreme contrast, like copies of black and white line work. For subjects that require the correct rendering of half-tones, it is always used with some high-potential developer like metol. Its secondary appellation, quinol, accounts for the abbreviation M-Q used to designate its very popular combination with metol. Hydroquinone deteriorates but slowly in air and has good keeping qualities in solutions, which do not stain either the gelatin or the hands. It is very sensitive to cold and should not be used at temperatures below 60° F. It is practically inert at 55°.

A formula for normal use, avoiding excessive contrast is

NORMAL HYDROQUINONE

Solution A

Sodium sulphite	700 gr.	100 g
Hydroquinone	140 gr.	20 g
Water to make	16 oz.	1000 cc

Solution B

Potassium carbonate	840 gr.	120 g
Water to make	16 oz.	1000 cc

Use equal parts of solutions A and B.

A typical developer using hydroquinone to produce extreme contrast is the Eastman D-9 tray developer for process films.

HYDROQUINONE-CAUSTIC (Eastman D-9)

<i>Solution A</i>		
Water (at 130° F.)	16 oz.	500 cc
Sodium bisulphite	$\frac{3}{4}$ oz.	22.5 g
Hydroquinone	$\frac{3}{4}$ oz.	22.5 g
Potassium bromide	$\frac{3}{4}$ oz.	22.5 g
Cold water to make	32 oz.	1000 cc
<i>Solution B</i>		
Cold water	32 oz.	1000 cc
Sodium hydroxide	$1\frac{1}{2}$ oz.	52.5 g

(Cold water should always be used when dissolving sodium hydroxide because considerable heat is evolved and if hot water is used the solution will boil violently and may spatter and cause serious burns on the hands or face.) Use equal parts of solutions A and B, and wash thoroughly after development, before fixing, to avoid stains. Use at 65° F.

METOL, Atolo, Elon, Genol, Monol, Pictol, Rhodol, Satrapol, Scalol, Viterol, $C_6H_4(OH)(NH\cdot CH_3)\frac{1}{2}H_2SO_4$, introduced in 1891 by Bogisch, for many years marketed only under the German trade-name Metol, is a soft-working developer of high energy, generally used in combination with some other developer, usually hydroquinone, chlorhydroquinone, glycin, or pyro. As a comparatively strong solution of sodium sulphite precipitates the free base of metol, the metol should be dissolved in the water before adding the sulphite. An alternative way which prevents any possibility of the oxidation of the metol before the sulphite can be added, is to first dissolve a small part of the sulphite in the water, add the metol, and after it is thoroughly dissolved add the balance of the sulphite. Metol solutions keep well. It is a soft-working developer, often used in cases of known underexposure.

Metol has had the reputation of causing a skin irritation similar to eczema on the hands of people susceptible to it. This is said to have been caused not by the metol itself, but by some impurities, notably a trace of paraphenylenediamine, often found in it. Manufacturers in later years have taken greater care to remove these impurities, and with this refined product metol poisoning is very rare. Those susceptible can avoid trouble by the use of rubber gloves or by dipping the hands in a saturated solution of paraffin in gasoline before using metol.

Some average formulas for the use of metol alone are:

METOL

Metol	150 gr.	17 g
Sodium sulphite	550 gr.	65 g
Sodium carbonate	550 gr.	65 g
Potassium bromide	16 gr.	1.8 g
Water to make	20 oz.	1000 cc

For use, dilute with 2 parts of water.

FINE-GRAIN METOL TANK DEVELOPER (Agfa 12)

Hot water (125° F.)	24 oz.	750	cc
Metol	120 gr.	8	g
Sodium sulphite	4 oz.	125	g
Sodium carbonate (monohydrated)	85 gr.	5.75	g
Potassium bromide	37 gr.	2.5	g
Water to make	32 oz.	1000	cc

For tray development the time is shortened by modifying the developer as follows:

FINE-GRAIN METOL TRAY DEVELOPER (Agfa 15)

(A vigorous, rapid tray developer, giving brilliant results)

Hot water (125° F.)	24 oz.	750	cc
Metol	120 gr.	8	g
Sodium sulphite	4 oz.	125	g
Sodium carbonate (monohydrated)	210 gr.	14	g
Potassium bromide	22 gr.	1.5	g
Water to make	32 oz.	1000	cc

A developer without alkali, giving softer negatives is:

METOL-SULPHITE DEVELOPER (Windisch)

Water	32 oz.	1000	cc
Metol	38.5 gr.	2.5	g
Sodium sulphite	3½ oz.	100	g

This is a *compensating developer* which brings out shadow detail without undue density in the highlights. For quicker, tray development, use about one-third as much water, but in that case the compensating effect is lost.

METOL-HYDROQUINONE, abbreviated to M-Q or M-H, is the most versatile, and most popular of all developers. The soft-working metol (Elon) and the density-giving hydroquinone make a combination superior in many ways to either of its constituents. It keeps well in solution, does not stain, and is faster than either metol or hydroquinone used alone. It can be made to give as much detail as metol alone and nearly as much contrast as hydroquinone.

The following is an average developer for general use in either tank or tray.

ELON-HYDROQUINONE (Eastman D-61a)

Stock Solution

Water (about 125° F.) (52° C.)	16 oz.	500	cc
Elon	45 gr.	3.1	g
Sodium sulphite	3 oz.	90	g
Sodium bisulphite	30 gr.	2.1	g
Hydroquinone	85 gr.	5.9	g
Sodium carbonate	165 gr.	11.5	g
Potassium bromide	24 gr.	1.7	g
Cold water to make	32 oz.	1000	cc

For tray use, take 1 part of stock solution to 1 part of water. Develop for about 7 minutes at 65° F. (18° C.).

For tank use, take 1 part of stock solution and 3 parts of water. At a temperature of 65° F. (18° C.), the development time is about 14 minutes.

While this developer does not produce negatives of warm tone, they have good printing density and quality and the developer has excellent keeping properties. It is one of the most satisfactory developers for continued use and, when kept up to normal volume, will give good results over a period of several weeks.

Replenishment: It is advisable to make up a greater quantity of stock solution than is needed to fill the tank. If the developer in the tank is of normal strength, but the volume of solution has been reduced, add a sufficient quantity of the surplus stock solution diluted 1 to 3 to fill the tank.

As with all tank developers, when not in use it should be covered with a floating lid or thin Kodaloid cut to the exact size of the tank and floated on the solution. The edges should be turned up to form a shallow boat. The surface of the developer should be skimmed each morning with the aid of a blotter.

If the strength of the solution, as well as the volume, has been reduced, add a sufficient quantity of replenisher (Formula D-61R).

REPLENISHER SOLUTION (Eastman D-61R)
(For Formula D-61a [tank dilution])

Stock Solution A

Water (about 125° F.) (52° C.)	96 oz.	3000 cc
Elon	85 gr.	5.9 g
Sodium sulphite	6 oz.	180 g
Sodium bisulphite	55 gr.	3.8 g
Hydroquinone	170 gr.	11.9 g
Potassium bromide	45 gr.	3.1 g
Cold water to make	192 oz.	6000 cc

Stock Solution B

Sodium carbonate	8 oz.	240 g
Water to make	64 oz.	2000 cc

For use take 3 parts of solution A and 1 part of solution B and add to the tank of developer as needed. Do not mix these solutions until ready to use.

The earliest of the fine-grain formulas featuring a high concentration of sodium sulphite (see page 86) was the Eastman D-76 which was modified by many other dealers, but probably never excelled.

ELON-HYDROQUINONE-BORAX DEVELOPER (Eastman D-76)
(For low contrast and maximum shadow detail on panchromatic films
and plates and Panatomic film)

Water (about 125° F.) (52° C.)	96 oz.	3000 cc
Elon	116 gr.	8 g
Sodium sulphite	13½ oz.	400 g
Hydroquinone	290 gr.	20 g
Borax, granular	116 gr.	8 g
Cold water to make	128 oz.	4000 cc

Use without dilution.

For tank use, develop about 20 minutes at 65° F. (18° C.) in the fresh developer. Greater or less contrast may be obtained in a longer or shorter time than that indicated. Develop Eastman Infra-red Sensitive Plates in a tank about 15 minutes at 65° F. (18° C.).

For tray use, decrease the time about 20 per cent.

A faster working developer may be obtained by increasing the quantity of borax. By increasing the borax about ten times (from 116 grains to 2 ounces, 290 grains per gallon) (from 8 grams to 80 grams per 4 liters) the development time will be about one-half that of regular D-76.

REPLENISHER SOLUTION (Eastman D-76R)

(For use with Developer D-76)

Water (about 125° F.) (52° C.)	96 oz.	3000 cc
Elon	175 gr.	12 g
Sodium sulphite	13½ oz.	400 g
Hydroquinone	1 oz.	30 g
Borax, granular	2 oz., 290 gr.	80 g
Cold water to make	128 oz.	4000 cc

Use the replenisher without dilution to maintain the level of the solution.

With use, the D-76 developer becomes slightly muddy, due to formation of a suspension of colloidal silver, and the tank usually becomes coated with a thin deposit of silver. Both these effects are harmless, however, and may be ignored.

After standing, M-Q-Borax developers increase in alkalinity, thus becoming more active, requiring less developing time, and producing coarser grain. With boric acid added as a buffer, the alkalinity of the developer (*pH*) (see page 70) remains constant.

M-Q BUFFERED BORAX DEVELOPER

Metol	28 gr.	2 g
Sodium sulphite	3 oz., 88 gr.	100 g
Hydroquinone	70 gr.	5 g
Borax, granular	110 gr.	8 g
Boric acid, crystals	110 gr.	8 g
Water to make	32 oz.	1000 cc

Another popular developer using borax is

FINE-GRAIN BORAX TANK DEVELOPER (Agfa 17)

Hot water (125° F.) (52° C.)	96 oz.	750 cc
Metol	88 gr.	1.5 g
Sodium sulphite	10½ oz.	80 g
Hydroquinone	¼ oz., 70 gr.	3 g
Borax	¼ oz., 70 gr.	3 g
Potassium bromide	30 gr.	0.5 g
Water to make	128 oz.	1000 cc

Do not dilute for use.

Development time at 65° F. (18° C.), 10 to 15 minutes for fine-grain films, 12 to 20 minutes for direct copy, direct duplicating, and portrait cut films.

RENEWAL FORMULA FOR AGFA 17

(Add whenever necessary to keep tank up to full volume)

Hot water (125° F.) (52° C.)	96 oz.	750 cc
Metol	¼ oz., 20 gr.	2.2 g
Sodium sulphite	10½ oz.	80 g
Hydroquinone	½ oz., 50 gr.	4.5 g
Borax	4 oz.	30 g
Water to make	128 oz.	1000 cc

To produce more contrast, the proportion of hydroquinone and of carbonate is increased.

HIGH CONTRAST DEVELOPER (Eastman D-19)

Stock Solution

Water (about 125° F.) (52° C.)	64 oz.	2000 cc
Elon	128 gr.	8.8 g
Sodium sulphite	12 oz., 360 gr.	384 g
Hydroquinone	1 oz., 75 gr.	35.2 g
Sodium carbonate	6 oz., 180 gr.	192 g
Potassium bromide	300 gr.	20 g
Cold water to make	128 oz.	4000 cc

Use without dilution. Development at 65° varies from 2½ to 5 minutes, depending upon the type of emulsion and the degree of contrast desired. With this, as with all highly-concentrated developers, the negative should be thoroughly rinsed between development and fixation, to prevent stains.

Caustic soda and a higher concentration of the reducing agents are used to get the utmost density in a negative. As the reducing agents are more soluble in alcohol than in water, wood alcohol is often added to the solution so that it can be made up in more concentrated form.

MAXIMUM ENERGY DEVELOPER (Eastman D-82)

(For underexposed negatives)

Water (about 125° F.) (52° C.)	24 oz.	750 cc
Wood alcohol	1½ oz.	48 cc
Elon	200 gr.	14 g
Sodium sulphite	1½ oz.	52.5 g
Hydroquinone	200 gr.	14 g
Sodium hydroxide (caustic soda)	125 gr.	8.8 g
Potassium bromide	125 gr.	8.8 g
Cold water to make	32 oz.	1000 cc

Develop about 5 minutes in a tray at 65° F. (18° C.).

The prepared developer does not keep more than a few days. If wood alcohol is omitted and the developer is diluted, the solution is not as active as in the concentrated form. This developer gives the greatest possible density with negatives having a minimum exposure.

When extreme speed in developing is necessary it can be secured without undue loss of quality by using the following developer for about 2 minutes at 65° F. The time can be shortened to 1 minute by using the developer at 86° F.; or to ½ minute at that temperature for use in continuous developing machines only, by adding 12 minims per ounce (25 cc per 1000 cc) of strong ammonia. In tank or tray, development will not be uniform unless it lasts at least 1 minute.

ULTRA RAPID DEVELOPER

Metol	61 gr.	14 g
Sodium sulphite	½ oz.	50 g
Hydroquinone	61 gr.	14 g
Caustic soda	83 gr.	19 g
Potassium bromide	39 gr.	9 g
Water to make	10 oz.	1000 cc

PARAMINOPHENOL, Paramidophenol, $C_6H_4(OH)(NH_2) \cdot HCl$, which was introduced by Lumière and Seyewetz in 1891, has the advantage that with a caustic alkali it can be prepared in a very highly concentrated solution, which has remarkable keeping qualities, and when diluted with appropriate amounts of water forms a very efficient developer for either negatives or papers. Stock solutions are marketed under the names Rodinal, Agfanol, Azol, Activol, or Certinal which are very widely used on account of their convenience.

A formula for a developer ready to use is as follows:

PARAMINOPHENOL (One solution)

Paraminophenol hydrochloride	31 gr.	4 g
Sodium sulphite	310 gr.	40 g
Sodium carbonate	310 gr.	40 g
Water	16 oz.	1000 cc

This does not keep so well as the two-solution stock formula:

PARAMINOPHENOL (Two solution)

Solution A

Paraminophenol hydrochloride	154 gr.	20 g
Water	16 oz.	1000 cc

Solution B

Sodium sulphite	460 gr.	60 g
Potassium carbonate	2 oz., 45 gr.	120 g
Water	32 oz.	2000 cc

Mix 1 part of solution A with 2 parts of solution B. This is more suitable for papers or transparencies than for negatives.

For the best keeping qualities, caustic soda instead of a carbonate must be used for the alkali. The following formula gives a stock solution very similar to the proprietary developers mentioned above.

PARAMINOPHENOL

Stock Solution

Water	10 oz.	625 cc
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Boil, allow to cool for 5 minutes, and add a few crystals of potassium metabisulphite; then add:

Paraminophenol hydrochloride	384 gr.	50 g
Potassium metabisulphite	2 oz., 277 gr.	150 g

Stir until dissolved. Then make a solution of:

Caustic soda	3 oz., 218 gr.	215 g
Water	8 oz.	500 cc

and add with constant stirring about 6 ounces (340 to 350 cc) to the paraminophenol solution. At first a precipitate of the paraminophenol base is formed,

but, as more caustic soda is added, this dissolves. Enough soda solution should be added to nearly dissolve the precipitate; then add:

Water to make 16 oz. 1000 cc

Bottle and allow to cool. Should any paraminophenol crystallize out, more soda must be added to nearly dissolve it. It is very important to leave some undissolved. For use mix 1 part with 10 parts of water with some bromide for plates and films, and with up to 40 parts of water for papers.

PARAPHENYLENEDIAMINE, Para D, Paramine, Diamine, Dianol, $C_6H_4-(NH_2)_2$, introduced by Andresen in 1888, is the free base, which is slightly alkaline and may be used without an alkali. The hydrochloride, Paramine H, Diamine H, etc., $C_6H_4(NH_2)_2 + 2HCl$, is acid and must be used with an alkali. Although generally harmless in solution, both of them in the dry state are poisonous to many people whose hands should be protected by rubber gloves when handling them. This developer at first found little favor because its low reduction potential caused both an excessive loss of emulsion speed and a long developing time. In 1904 Lumière and Seyewetz called attention to the unparalleled fine grain which it produced, but it was not until nearly twenty-five years later that it was used extensively, and then usually in combination with some other developer which increased the emulsion speed and reduced developing time, but always at some sacrifice of grain size. A negative developed in paraphenylenediamine is deceptive in appearance, as the printing density is often greater than the visual density. (See pages 86-89.)

PARAPHENYLENEDIAMINE DEVELOPER

Paraphenylenediamine (base)	77 gr.	10 g
Sodium sulphite	460 gr.	60 g
Water to make	16 oz.	1000 cc

The paraphenylenediamine should first be dissolved in water at about 160° F., and the sulphite then added. Mix no more than will be used in one day, as it does not keep well.

With this developer, up to six times normal exposure must be given.

The hydrochloride instead of the free base is used in the following:

PARAPHENYLENEDIAMINE HYDROCHLORIDE

Paraphenylenediamine hydrochloride	90 gr.	6 g
Sodium sulphite	750 gr.	50 g
Trisodium phosphate	180 gr.	12 g
Water to make	32 oz.	1000 cc

With the above developers, the time of development varies from 30 to 50 minutes at 65° F., depending upon the kind of emulsion and the degree of contrast desired.

A great increase in emulsion speed, while sacrificing but little in graininess, is obtained by adding glycine to the formula. Dr. Sease of the DuPont film laboratory (see page 87), has produced a series of such formulas, of which the most popular is:

PARAPHENYLENEDIAMINE-GLYCIN (Sease ND-3)

Water (125° F.)	31 oz.	975 cc
Sodium sulphite	3 oz.	90 g
Paraphenylenediamine (base)	146 gr.	10 g
Glycin	29 gr.	2 g
Water to make	32 oz.	1000 cc

This developer necessitates from 50 per cent to 100 per cent more than normal exposure, and at 68° F., develops fast emulsions to a gamma of 0.7 in about 25 minutes in a tank with occasional agitation.

Compromise developers are used in cases where it is impossible to increase the exposure time enough to take full advantage of the ability of paraphenylenediamine to give fine grain. Metol or pyro, which help the shadow detail, are added to the combination of paraphenylenediamine-glycin. The Edwal 12 and Champlin 15 formulas, given on pages 87 and 88, are typical of such compromise developers.

PYROCATECHIN, Elconal, Katchin, $C_6H_4(OH)_2$, introduced by Eder and Toth in 1887, is a developer more energetic than hydroquinone, which it closely resembles chemically, differing only in the position of its parts in the benzene nucleus (see page 68). As it offers no advantage over other less expensive developers, it is little used, and seldom occurs in formulas except of German origin. It has the unique ability to develop normally in the presence of hypo, and this has led to its being utilized for processes of combined developing and fixing, but none of them appear to be very practical or reliable because the two operations are not equally affected by temperature, so that it is difficult to conclude them in the same time.

PYROCATECHIN

Stock Solution A

Pyrocatechin	8 gr.	1 g
Water	16 oz.	1000 cc

Stock Solution B

Potassium carbonate	1 oz.	200 g
Water	5 oz.	1000 cc

For use mix 10 parts solution A with 1 part solution B. Gives brownish images, suitable for transparencies. The developer can only be used once, as it spoils rapidly.

PYROCATECHIN (One solution)

Potassium metabisulphite	2 oz.	100 g
Potassium carbonate	3 oz.	150 g
Water	8 oz.	400 cc

Mix in a mortar and add:

Pyrocatechin	7 oz.	350 g
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This forms a thick cream which must be stored in well-stoppered bottles filled to the top. Mix 1 part with 20 parts of water.

PYROCATECHIN-POTASH

Stock Solution A

Pyrocatechin	3 oz., 224 gr.	200 g
Sodium sulphite	7 oz.	400 g
Water	16 oz.	1000 cc

Stock Solution B

Potassium carbonate	922 gr.	120 g
Water	16 oz.	1000 cc

For use, mix in equal parts.

The following developer, proposed by Windisch, is compensating in its action, and can be made to give printable negatives from subject matter of extremely harsh contrasts, as when electric lights are included in a picture.

PYROCATECHIN COMPENSATING DEVELOPER

Solution A

Water	3½ oz.	100 cc
Pyrocatechin	118 gr.	8 g
Sodium sulphite	19 gr.	1.25 g

Solution B

10 per cent Caustic soda

For normal use, take 12 parts solution A, 7 parts solution B, 500 parts water. If the negative material is innately contrasty, use 20 parts solution A, 5 parts solution B. Agitate constantly during development. Normal development is 15 to 20 minutes at 65° F., but as the shadows come up rapidly in this developer, very soft negatives can be made by short development. The image is brown, giving it good printing quality. Solution A keeps well in bottles filled to the top, but solution B keeps for only a few weeks.

PYROGALLOL, Pyro, Pyrogallie Acid (incorrectly), $C_6H_3(OH)_3$, introduced by Regnault in 1851, has been in use longer than any other organic developer and is one of the most popular. When used with normal concentrations of sulphite it gives a characteristic stain, not only to the gelatin, but to the fingers and nails of the worker unless they are protected by rubber gloves. (See page 336 for stain remover.) The staining of the gelatin is often considered a distinct asset, as it gives the negative a printing resistance which is very desirable in some positive processes. As the image is a compound of silver and pyro stain, it is often used in cases of known underexposure, the stain reinforcing the silver image enough to make very thin negatives printable. If pyro is used with four or five times its own weight of anhydrous sodium sulphite, it gives a black image, without stain. As the density of the pyro stain occurs in the same proportion as the density of the silver image, it is possible with a heavily stained negative to bleach away the silver image entirely and print from the stain alone, which has a very fine-grained image. In tank development, pyro should have at least occasional agitation, but in tray development gentle agitation should be continuous to prevent reticulation markings. Pyro tans and toughens gelatin more than any other developer. Warm tones which are very pleasing on lantern slides, are readily secured

with pyro by using acetone. Maximum energy of the developer is obtained by using a caustic alkali which must not exceed the proportion of 45 parts of caustic potash or 32 parts of caustic soda to 100 parts of pyro, or intense fog will result. Ammonia was once quite generally used as the alkali with pyro, but on account of its unstable qualities other alkalis are preferable. Pyro oxidizes so rapidly in developing solutions that it can be used only once, and it is usually kept in two separate stock solutions, one containing the alkali, and the other the pyro with the sodium sulphite and a small amount of acid, usually sodium bisulphite, because pyro is relatively stable only in an acid solution. Many people think that pyro gives a cleaner-cut and more definite separation of tones than any other developer and it is very popular with workers in gum and carbon, for both direct and copy negatives.

HURTER AND DRIFFIELD STANDARD DEVELOPER
(For plate testing)

Pyrogallol	8 parts
Sodium carbonate (crystals)	40 parts
Sodium sulphite (crystals)	40 parts
Water	1000 parts

PYRO-AMMONIA

Solution A

Sodium sulphite	384 gr.	50 g
Sulphuric acid	3 drops	6 drops
Pyrogallol	107.5 gr.	14 g
Water	8 oz.	500 cc

Solution B

Potassium bromide	10 per cent solution
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Solution C

Ammonia, specific gravity 0.91	4 oz.	200 cc
Water	20 oz.	1000 cc

For use mix 5 parts solution A, 1 part solution B, 5 parts solution C, and 50 parts water.

A pyro formula which has been a favorite for many years is the "B-J":

BRITISH JOURNAL PYRO-SODA

Solution A

Sodium sulphite (crystals)	640 gr.	148 g
Potassium metabisulphite	80 gr.	18.3 g
Pyro	80 gr.	18.3 g
Potassium bromide	20 gr.	4.6 g
Water to make	10 oz.	1000 cc

Solution B

Sodium carbonate (crystals)	640 gr.	148 g
Water to make	10 oz.	1000 cc

In the A solution, dissolve the sulphite and the metabisulphite first, and then add the pyro. The working solution is normally solution A, 1 part; solution B, 1 part; water, 2 parts, but it can be used at different concentrations. The two stock solutions have exceptional keeping qualities.

For great contrast, suitable for black-and-white line work, or photo-mechanical or process plates, use:

PYRO-AMMONIA FOR CONTRAST

<i>Stock Solution A</i>		
Pyrogallol	54 gr.	7 g
Ammonium bromide	54 gr.	7 g
Potassium metabisulphite	54 gr.	7 g
Water	16 oz.	1000 cc
<i>Stock Solution B</i>		
Ammonia, specific gravity 0.91	160 minims	21 cc
Water	16 oz.	1000 cc

For use mix in equal volumes.

A very rapid, stainless developer, acting very much like metol, is

PYRO-CAUSTIC (Valenta)

<i>Stock Solution A</i>		
Sodium sulphite	615 gr.	80 g
Pyrogallol	192 gr.	25 g
Water	16 oz.	1000 cc
<i>Stock Solution B</i>		
Caustic potash	88.3 gr.	11.5 g
(or Caustic soda)	65.3 gr.	8 g
Water	16 oz.	1000 cc

For use mix 1 part solution A, 1 part solution B, and 1 part water.

The standard, three-solution, or "A B C" formula is probably the most popular form in which pyro is used, and different manufacturers' formulas vary but slightly from the following:

THREE-SOLUTION PYRO DEVELOPER (Eastman D-1) (For warm tones using tray or tank)

<i>Stock Solution A</i>		
Sodium bisulphite	140 gr.	9.8 g
Pyro	2 oz.	60 g
Potassium bromide	16 gr.	1.1 g
Water to make	32 oz.	1000 cc
<i>Stock Solution B</i>		
Water	32 oz.	1000 cc
Sodium sulphite	3½ oz.	105 g
<i>Stock Solution C</i>		
Water	32 oz.	1000 cc
Sodium carbonate	2½ oz.	75 g

Prepare fresh developer for each batch of films. For tray development, take 1 part solution A, 1 part solution B, 1 part solution C, and 7 parts water. Develop about 6 minutes at 65° F. (18° C). For tank development, take 9 ounces each (285 cc) of solutions A, B, and C and add water to make 1 gallon (4 liters). Develop for about 12 minutes at 65° F. Any scum on the surface of the developer must be removed by means of a sheet of blotting paper before developing, or stains will result.

With pyro and some other developers (phenolic) the usual alkalis can be replaced by acetone ($\text{CH}_3\text{CO}\cdot\text{CH}_3$), which aids the dissociation of the sodium sulphite into sodium bisulphite and caustic soda, thereby providing the necessary alkali. It is used for plates, but should not be used for films.

PYRO-ACETONE (Lumière)

Solution A

Pyrogallol	768 gr.	100 g
Sodium sulphite	1536 gr.	200 g
Water	16 oz.	1000 cc

Potassium metabisulphite must not be used, nor must acid be added. For use mix solution A 8 parts, acetone 8 parts, and water 100 parts.

The addition of glycerin to pyro tends to give softer negatives.

PYRO-AMMONIA-GLYCERIN (Edwards)

Solution A

Pyrogallol	1 oz.	40 g
Glycerin	1 oz.	40 cc
Denatured alcohol	6½ oz.	250 cc
(methylated spirit)		

Solution B

Potassium bromide	65 gr.	15 g
Ammonia	1 oz.	40 cc
Glycerin	1 oz.	40 cc
Water	6½ oz.	250 cc

For use mix 1 part solution A, 1 part solution B, and 30 parts water.

A rapid formula for tray development, largely used for transparencies and copy negatives, is:

SPECIAL PYRO TRAY DEVELOPER (Eastman D-84)

Stock Solution A

Water	24 oz.	750 cc
Sodium sulphite	6 oz.	180 g
Pyro	1 oz.	30 g
Water to make	32 oz.	1000 cc

Stock Solution B

Water	32 oz.	1000 cc
Sodium carbonate,	4 oz.	120 g
Potassium bromide	55 gr.	3.8 g

For use take 1 part solution A, 1 part solution B, and 4 parts water. Develop about 4 minutes at 65° F. (18° C.).

MINOR DEVELOPERS. — There are some other developers which are of minor importance because they are so little used, or because their manufacture has ceased.

Chloranol was brought out in 1913 by Lumière and Seyewetz for use in some of the Lumière formulas. It is a combination of hydroquinone monochloride and metol base.

Diogen, an acid aminonaphthol disulphonate of sodium, which was very similar to eikonogen, has given place to metol.

Duritol, a form of paraminophenol, appeared in 1910 but is no longer obtainable.

Edinol is similar to metol, but seldom used, except by people who are subject to metol poisoning. It is less energetic than metol.

Eikonogen, introduced by Andresen in 1889, was supplanted by metol to which it is distinctly inferior.

Hydramine, a combination of hydroquinone and paraphenylenediamine, was introduced by Lumière and Seyewetz in 1899, but is no longer manufactured.

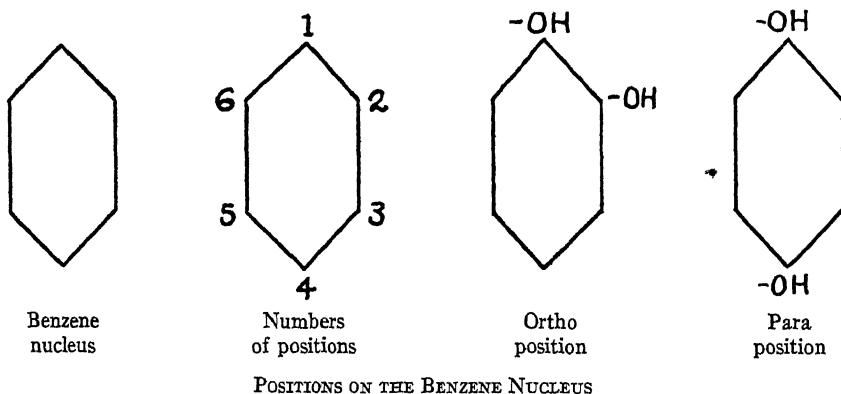
Metoquinone, a chemical combination of metol and hydroquinone, was brought out by Lumière in 1903, for use with the Lumière Autochrome color process.

Monomet appeared in 1916 as a substitute for metol.

Neol, a compensating developer for the correction of overexposure, was brought out by Hauff in 1918.

Ortolis is very similar to pyro, but does not stain, and keeps better in solution.

DERIVATION OF DEVELOPERS. — All the developers in common use, as listed above, are either *para* or *ortho* diphenols, diamines, or aminophenols, derived from benzene, and their names indicate the position of their groups on



the hexagonal benzene nucleus. When the groups are adjacent in the 1 and 2 position, they are said to be *ortho*; when they are opposite, in the 1 and 4 position, they are called *para*.

SOLUBILITY OF DEVELOPING AGENTS. — When a solid, a gas, or another liquid is dissolved in a liquid it forms a homogeneous *solution*. The substance

dissolved is called the *solute*, and the liquid in which it dissolves, the *solvent*. At any given temperature, a solvent dissolves only a given amount of a solid, and when this maximum has been reached, the solution is said to be a *saturated solution*, and this degree of concentration is called the *solubility* of the solid at that temperature. Unless another liquid is mentioned, water is assumed to be the solvent.

SOLUBILITY OF DEVELOPING AGENTS AT 60° F.

Diaminophenol	1 in 4
Glycin	0.23 g per 1000 cc
Hydroquinone	5.7 g per 1000 cc
Metol	4.8 g per 1000 cc
Paraminophenol (base) HCl	33.0 g per 1000 cc
Paraphenylenediamine (base)	Soluble only in very hot water
Paraphenylenediamine hydrochloride	Very soluble
Pyrocatechin	33.0 g per 1000 cc
Pyrogallol	52.4 g per 1000 cc

REDUCTION POTENTIAL. — The relative reducing energy of developers is shown by comparing them with hydroquinone which is taken as a standard. Some of the more common ones rate as follows:

Paraphenylenediamine	0.4
Hydroquinone	1
Glycin	1.6
Paraminophenol	6
Chlorhydroquinone	7
Pyrocatechin	7
Pyrogallol	16
Metol	20
Adurool	21
Amidol	30-40

PRESERVATIVES. — As all organic developers oxidize rapidly, it is necessary to add a preservative to developing solutions to retard the rate of oxidation. On account of its cheapness and efficiency, *sodium sulphite* (Na_2SO_3) is the preservative most commonly used. This is the anhydrous, or desiccated form 1 part of which is equal to 2 parts of the crystals ($\text{Na}_2\text{SO}_3 \cdot 7\text{H}_2\text{O}$). This form is usually preferred because it keeps better, and is not so heavy or bulky. The anhydrous and the crystal forms may be substituted for each other in any formula on the above ratio, first taking care that the crystals are pure. They oxidize rapidly and after storage are likely to be covered with a fine powder of sulphate or carbonate which should be rinsed off and the crystals dried again before weighing out for use. The anhydrous form is readily soluble in cold water, and doubly so in water of about 100° F., but there is no advantage in using water hotter than this, as the sulphite will not dissolve in it until it has cooled down. If used at greater than recommended concentration, sodium sulphite retards development on account of its solvent action upon silver halide, and tends to increase fog.

The *British Journal of Photography* has recommended a neutral stock solution of sodium sulphite which may be used in place of the ordinary sulphite for any developing agent, and is particularly valuable with pyro.

"B-J" NEUTRAL SULPHITE

Sodium sulphite	2 oz.
Potassium metabisulphite	$\frac{1}{2}$ oz.
Water	20 oz.

Dissolve the salts in the water at ordinary temperature, raise to the boiling point, and immediately cool.

Sodium bisulphite, (NaHSO_3), is often used, wholly or in part, to replace sodium sulphite in a developer, because it has less tendency to fog the emulsion. Sodium bisulphite may be substituted weight for weight in any formula for *potassium metabisulphite* with which it is practically identical, at half the cost.

ACCELERATORS. — Most reducing agents will not develop an emulsion, or at least not in any practical length of time, except in an alkaline solution. The alkalis most commonly used are the carbonates, the caustics, the basic phosphates, and the borates. The alkali softens the gelatin of the emulsion, allowing the developer to penetrate it more readily, so that a deficiency of alkali retards development. And excess of alkali results in chemical fog, and an overswelling of the gelatin which causes frilling and blisters.

The degree of acidity or alkalinity of a solution is expressed by the symbol *pH*. The acidity of a solution is due to the presence of free hydrogen ions, and the alkalinity of a solution is due to the presence of free hydroxyl ions. In an acid solution there is an excess of hydrogen ions over hydroxyl ions, and in an alkaline solution an excess of hydroxyl ions over hydrogen ions. The degree of acidity or alkalinity is designated in terms of *pH* which is the logarithm of the reciprocal of the hydrogen ion concentration ($pH = \text{Log } \frac{1}{H}$ ion concentration). Pure water has a *pH* of 7.0; solutions containing borax, 8.0 to 9.0; those containing carbonate, 9.5 to 10.5; and those containing caustic soda 11.0 to 12.0 or more.

Sodium carbonate, the alkali most commonly used in developing solutions, is furnished in three forms — crystal ($\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$), monohydrated ($\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$), and anhydrous (desiccated) (Na_2CO_3). On storage, the crystals lose water and the anhydrous, if exposed to the air, tends to take up water, both tending to approach the strength of the monohydrated which remains very constant. For that reason the monohydrated is preferred by some workers, but experiments have shown that if the anhydrous is stored with reasonable care in a closed bottle or can, the quantity of water absorbed rarely has any appreciable photographic effect. All the formulas in this book are based upon the use of the anhydrous form unless otherwise specified.

In formulas written for the anhydrous, increase the amount 17 per cent if the monohydrated is used, or three times if the crystal is used.

Potassium carbonate (K_2CO_3), is more soluble than sodium carbonate, and so is sometimes preferred for highly concentrated solutions. The two salts may be used interchangeably, weight for weight, the error caused by the difference in molecular weight being negligible for photographic purposes. Potassium carbonate readily takes up water from the air and must be kept in tight containers. It is more expensive than sodium carbonate and offers no advantages except in the matter of solubility.

Ammonium carbonate ($(NH_4)_2CO_3 \cdot H_2O$) is quite often used in developers for warm tone lantern slides. This salt is often covered with a white oxidation product which must be rinsed off and the lumps dried before weighing. It should be mixed in cold water as it decomposes in hot water.

Caustic alkalis like *sodium hydroxide* (NaOH), and *potassium hydroxide* (KOH), are used with developers of low energy, to produce great density and high contrast. They must be kept protected from the air, as they absorb moisture and carbon dioxide. They should be dissolved in cold water as they generate considerable heat. Both are very corrosive and the hands should be rinsed after handling them. Caustic alkalis are avoided in fine-grain development because they soften and swell the gelatin more than other alkalis do.

Ammonia (NH_4OH) is a gas in a solution of water from which it is constantly escaping, so that the strength of the solution is always uncertain, and its action consequently not dependable. The saturated solution, of 0.880 density, contains about 35 per cent of the gas, but is much less stable than a solution of 0.923 density containing 19 per cent of the gas.

Tribasic sodium phosphate ($Na_3PO_4 \cdot 12H_2O$) is used, principally in fine-grain developer formulas, because it supplies a permanent reserve of caustic soda without causing excessive swelling and softening of the gelatin.

Acetone ($CH_3CO \cdot CH_3$) is sometimes used with the phenolic developers in place of an alkali. It dissociates the sodium sulphite into sodium bisulphite and caustic soda. It gives negatives notably free from fog and stain, and for that reason was once much used when developing plates with pyro. It should not be used with films, as it has a tendency to detach the emulsion from the celluloid base.

Borax ($Na_2B_4O_7 \cdot 10H_2O$) is much used with low contrast developers for fine grain. It is sometimes called a "buffer" alkali (developers in which it is used are often called "buffered" developers) because in solution it slowly and constantly forms an alkali, keeping the *pH* of the solution constant, with at no time an undue concentration of alkali that would disrupt the gelatin and facilitate the clumping of the silver grains.

THE RESTRAINER. — *Potassium bromide* (KBr) is added to a developer to restrain fog, and to minimize the effects of overexposure. In developing a

negative, there is always a slight, over-all reduction of silver, regardless of the action of light. This slight deposit is known as fog, and potassium bromide has a greater restraining action upon it than it has upon the latent image. Fog was once a considerable factor in development and bromide had to be added to the developer to get a clean negative, but improvements in manufacturing processes have reduced the tendency to fog to such an extent that many formulas do not call for bromide. Free bromide is always liberated from the emulsion during development, and when none has been included in the formula, this action is often hastened by conditioning the developer by letting it work on a few scraps of old film, or by adding a small amount of used developer to the new before using it.

The extreme latitude of most emulsions now makes it seldom necessary to use bromide to overcome the effects of overexposure. Bromide does have a restraining effect on development, especially noticeable in shadow details, so that it practically reduces the speed of an emulsion.

By delaying the appearance of fog, bromide makes it possible to develop negatives to a higher gamma than could otherwise be done.

WATER. — Water, unless distilled, is likely to contain many impurities, of a wide variety. These are usually present only in such minute quantities that they have no deleterious effect upon photographic solutions. The concentration of chlorine in water chlorinated for drinking purposes is too small to cause trouble, and the same is true of the copper sulphate often added to water supplies to kill vegetable and bacterial growths. The impurities found in water may be dissolved salts; suspended particles of iron, sulphur, vegetable matter, or dirt; extracts from decayed vegetable matter or the bark of trees; or gases. If the water is boiled and then allowed to settle, the gases are thrown off during the boiling and the other matter precipitated. If boiled water is allowed to stand until the precipitated matter has settled, the pure, supernatant liquid can be decanted for use. With this precaution, it is very rare that impurities in water cause any trouble in photographic solutions. The actual test is to mix a developer with water so prepared and try it out by comparison with the same developer mixed with distilled water. Distilled water is inexpensive, and readily obtainable in most places, and its use, especially in stock solutions, is advisable if there is any doubt about the water.

Hydrogen sulphides and soluble metallic sulphides, if present only in very small quantities in developers, will occasion fog, and these are the only impurities in water ever likely to give serious trouble. They can be removed by adding to the water 1 grain of lead acetate for each 2 ounces of developer, and allowing the developer to stand until the impurities settle out.

Fixing baths seldom give any trouble with any kind of water if the bath is allowed to clarify itself by settling before use.

During washing, photographic emulsions are usually sufficiently protected from all impurities in water by using a commercial filter, or two or three

layers of cheesecloth or cotton flannel over the faucet, and by removing all excess moisture from the film before drying. Water that even after ordinary filtration is colored brown by extracts from vegetable matter, is likely to stain a negative, but it can usually be purified by filtration through activated charcoal.

SEA WATER cannot be used for mixing photographic solutions because it contains quite a large proportion of soluble salts, but it may be used for washing. It effectively removes hypo, but leaves in the emulsion its own salts which must be removed by a final short washing or soaking in fresh water to prevent the negative from fading.

MIXING SOLUTIONS. — Chemicals should be weighed on sheets of paper placed on the pans of the scales. It is convenient to cut a supply of papers all of the same size and weight. The scale is balanced by placing a paper on each pan, one to receive the chemical, and the other to balance the scale. Errors are avoided by weighing out all the chemicals, each on a separate paper on which the name and weight are penciled, before starting to mix a solution. They can then be arranged on the bench in the order of their use, and checked. Chemicals should be sifted into the water while it is being vigorously stirred. If the water is poured on to the chemical, it is likely to cake, and can then be dissolved only with difficulty. Dissolve each chemical thoroughly before adding another to the solution. Avoid, as much as possible, introducing air into the solution, as is done when a solution is shaken in a beaker. For containers, use glass, enameled ware, or hard rubber. Tin, copper, or galvanized iron react with ingredients of the developer to cause fog.

For most developers, the sulphite should be dissolved first, so that it will retard the oxidation of the reducing agent when it is added. Metol is the notable exception to this as it is not soluble in a strong solution of sulphite, and it oxidizes so slowly that no harm is done by dissolving it in the plain water and then adding the sulphite promptly. An alternative way is to first dissolve a little of the sulphite, follow with the reducing agent, and then add the balance of the sulphite, but this is not really necessary if the sulphite follows the metol into the solution promptly.

Use water at about 125° F. unless other temperatures are specifically recommended. Caustic soda generates considerable heat when it dissolves and should be dissolved separately in *cold* water and then slowly stirred into the rest of the developer. Intense heat is also generated by combining sulphuric acid and water. Always *add the acid to the water*, and never the reverse, or serious injury may result from its spattering. Add the acid slowly, or the sudden heat may break the container, if it is glass.

Filtering is not usually necessary if the water and the chemicals are clean. Any ordinary sediment will be precipitated if the solution is allowed to stand without agitation until cooled. If filtering is necessary it is usually sufficient to filter through absorbent cotton or fine cloth that has been well washed to

remove any sizing matter it might contain. Filtering through paper or fabric is a slow process and to be avoided as much as possible because it exposes the solution to the air, causing it to oxidize.

KEEPING STOCK SOLUTIONS. — A developer prepared with water that has been freed from air by being boiled and allowed to settle can be kept without deterioration almost indefinitely, if protected from the air. This means that it must be kept in a bottle filled to the top so that there is no air in the container above the solution, and that the top is sealed against the entrance of air. Air enters through an ordinary cork, but it can be sealed by dipping the neck of the bottle, including the cork, in melted paraffin. Oxidation occurs in direct proportion to the amount of air that finds its way into the container, and is usually apparent from the change of color of the developer, but with metol-hydroquinone the developer is sometimes oxidized without change of color.

LIFE OF DEVELOPERS IN USE. — Developers deteriorate in use from destruction of the reduction agent as it performs its function; from oxidation; and from the accumulation of oxidation products and of bromide in the developer. Replenishing solutions are added to tank developers from time to time to restore the balance of the developer. The replenisher usually contains a larger proportion of the reducing agent and of alkali than did the original formula, the same amount of sulphite, and no bromide. After much use a developer is restrained by the accumulation of oxidation products and its lessened activity is most easily seen in the shadow detail, where it produces an effect similar to underexposure, particularly noticeable when developing to a low gamma. Prolonged development cannot wholly compensate for this, and the only remedy is a new developing solution, or the addition of replenisher to the old. A developer of the Eastman D-76 type can be kept in effective operation for many months by the addition of replenisher if the solution is occasionally filtered to remove the silver sludge and dirt, but it may eventually cause fog and stain.

Developers kept in open tanks oxidize rapidly because so large an area on the surface of the developer is exposed to air. Oxidation can be reduced to a minimum by fitting the tank with a floating cover of monel metal or stainless steel to protect the surface of the developer from air when it is not in use. A lid can be improvised by cutting a sheet of paraffin paper to size and floating it on the top. If the developer is kept in bottles when not in use, the bottles should be of the wide-mouthed variety so that the developer can be poured in and out with as little admixture of air as possible. Confectionery jars make good receptacles. The developer should fill the bottle up to the neck, to exclude all air. This level can be maintained as the volume of the developer is diminished in use, by putting glass marbles in the bottle.

The best way to test the efficiency of a developing solution is by the use of standardized negatives which are printed as needed from a master positive of a step-wedge. One negative is developed in the fresh developer under

fixed conditions, and kept as a standard. The developer is tested from time to time by developing an identical negative under identical conditions of time and temperature, and comparing it for highlight density and for the least exposure that it will record, the latter corresponding to shadow detail. Dundon, Capstaff, and Brown, in the April, 1930 issue of the *Journal of the Society of Motion Picture Engineers*, suggest that the time of fixation can be saved when making this test by plunging the negative, as soon as developed, for 15 seconds in the following bath, after which it can be examined and compared in bright light.

STOP BATH

Potassium iodide	300 gr.	20 g
Glacial acetic acid	315 minims	20 cc
Potassium alum	600 gr.	40 g
Sodium sulphite	15 gr.	1 g
Water to make	32 oz.	1000 cc

TIME OF DEVELOPMENT.—The rate of development depends upon the reducing energy of the developer; the temperature; and the characteristics of the emulsion. The relative reducing energy of different developers is shown on page 69. All developers work faster at higher temperatures. Fast emulsions develop more slowly than slow emulsions; in general, the development speed of an emulsion is in indirect ratio to its exposure speed.

With a given developer, the degree to which an emulsion develops depends upon the temperature of the developer and the length of time it is allowed to act. Development progressively increases contrast, so the time of development is fixed solely by the amount of contrast desired. Because this varies so greatly for individual needs and preferences, no absolute time of development can be established.

Contrast is measured in terms of gamma (see page 77). With a gamma of 1.0, the contrasts of the negative are the same as those of the original, but for various reasons this degree of contrast is seldom desired in a negative. A negative is only a means to an end, which is the print, and allowance must be made for changes in contrast inherent in different printing processes. Then, too, it is often desirable to have the contrasts in the print different from those in nature, so negatives are arbitrarily developed to different gammas. Portraits are usually developed to a lower gamma, and machinery to a higher gamma than would reproduce them as they were in nature. Pictures taken in dull light, where the contrasts are less than desired, are brightened up by slightly longer development. In pictorial work, contrasts are variously controlled by development to give special effects.

Whether or not a negative will print upon a given paper depends upon its density range in comparison to the exposure scale of the paper (see page 150). With any given brightness range in a subject photographed, the density range of the negative will vary with the degree of contrast to which it is developed,

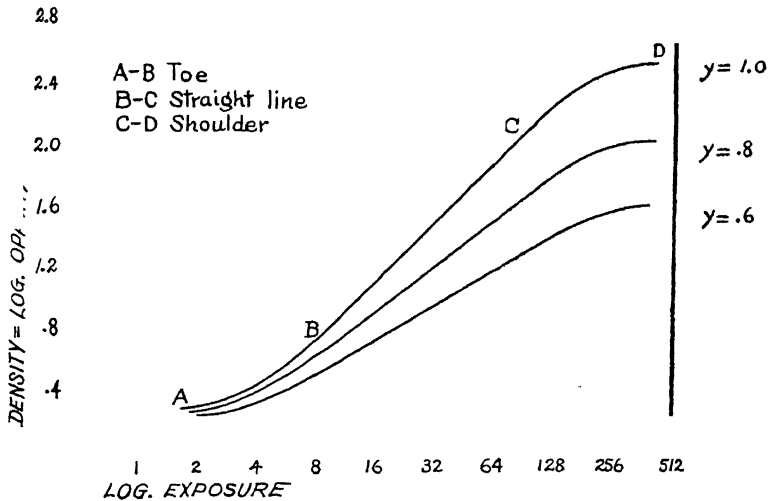
so subjects of different brightness range must be developed to different gammas if they are to be printed upon the same paper.

Fineness of grain is in indirect proportion to the length of development, and the degree of contrast of a negative that has to be greatly enlarged is definitely limited by this consideration.

From the foregoing, it will be seen that the degree of contrast desirable or permissible in a negative is governed by so many different considerations that there can be no fixed time for development. The best that can be done for a given emulsion and developer is to establish the time and temperature that will result in a certain gamma which experience has shown is best adapted for subjects of normal contrast upon the chosen printing medium. From this, intelligent changes can be made to produce negatives of greater or less contrast for special and specific needs. If occasional negatives developed by the standard process show too little or too great contrast on account of differences in the brightness range of the subject photographed, this can be changed by suitable reduction or intensification of the negatives, or they may be printed upon paper with a different degree of contrast from that normally used. (See Temperature Coefficient, p. 82.)

DENSITY. — The density of any given part of a negative is a measure of the light-intercepting power at that point. *Transparency* is the ratio between the incident light and the light that is transmitted through the negative. As no substance transmits all incident light, transparency is always less than unity. *Opacity* is the reciprocal of transparency and hence must always be greater than unity. The common logarithm of opacity is arbitrarily designated *density*. It should always be noted that the term as used photographically has this specific meaning. The *unit of density* is a deposit of silver that lets through 1/10 of the incident light. It corresponds to about 1/100 of a grain weight per square inch. As density is expressed in common logarithms, a density of 2 transmits 1/100 of the incident light, and a density of 3 transmits 1/1000 of the light.

THE CHARACTERISTIC CURVE of an emulsion is also called the *H & D* curve in honor of its originators, Hurter and Driffield, and also the *D-log E* (density versus the logarithm of exposure) curve from the method of obtaining it. An emulsion is given a series of increasing exposures by printing under a step-tablet which is calibrated so that the transmission of each step is known, or it is given a series of exposures to a light of known intensity, so that the amount of exposure causing each density in the negative is known. After standard development, the densities of the negative are measured by a densitometer and plotted on the ordinate of a graph against the logarithms of the exposures which are laid off on the abscissa. The graph, when plotted, takes the form of a curve with three distinct parts. The lower part of the curve, called the toe, is concave to the exposure axis, and represents the period of underexposure. The middle part of the curve, corresponding to correct



CHARACTERISTIC CURVES SHOWING DIFFERENT GAMMAS OBTAINED BY DIFFERENT TIMES OF DEVELOPMENT

exposure, is a straight line because each increase of exposure in this section has resulted in a corresponding increase in density. The upper part of the curve, called the shoulder, is reversed, with values no longer proportional, and it registers the effect of overexposure. From this curve there can be ascertained many of the characteristics of an emulsion, including its exposure latitude, its speed under certain conditions, its contrast, and the degree to which it can be developed.

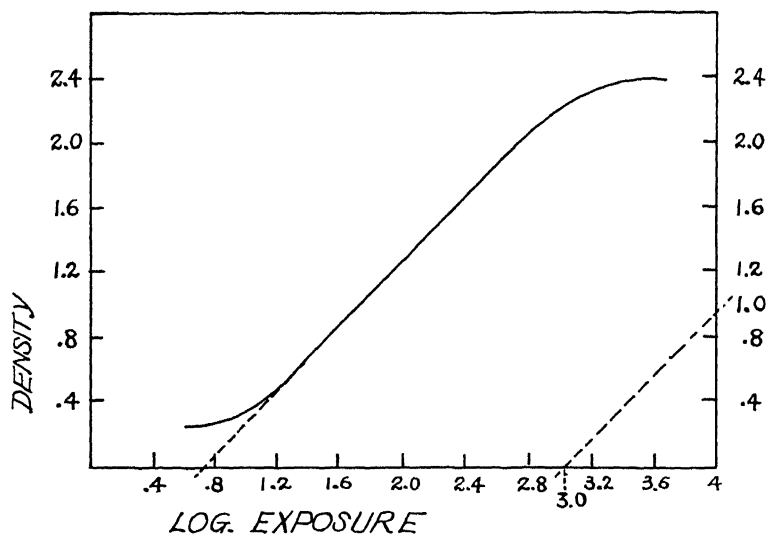
GAMMA (Greek letter γ) is a measure of the contrasts of a negative relative to the contrasts of the object that was photographed. A gamma of 1.0 means that the contrasts of the negative are the same as those of the object. A gamma of 0.8 means that the contrasts of the negative are only four-fifths as great as those of the object. Although both underexposed and overexposed parts of negatives may be used to a limited extent in photography, the areas of correct exposure are the only dependable ones, and it is from the straight-line portion of the characteristic curve, which represents the rate of increase in density from these correct exposures, that gamma is derived. Up to a certain point (see Gamma Infinity, below), gamma increases with the time of development. Increasing the time of development leaves the density *ratios* unchanged but increases proportionally the density *differences* represented by the straight-line portion of the curve, changing the gradient of the line and consequently its angle to the base. As the tangent of this angle varies with the density differences, it is an exact measure of the degree of development, and it was termed the *development factor* by Hurter and Driffield. They designated it by the Greek letter γ (gamma), and this shorter term is the one generally used.

Gamma is conveniently found from the graph by dividing the difference between any two densities appearing on the straight-line portion of the curve by the difference in log exposure times that occasioned them.

$$\text{Gamma} = \frac{D_2 - D_1}{\text{Log } E_2 - \text{Log } E_1}$$

To use this formula, erect two perpendiculars from the log exposure axis to intersect the straight-line portion of the curve. From the scale at the left, read the densities at the points of intersection and substitute the density and the log exposure value in the equation.

Hurter and Driffield used a simple, graphical method to obtain gamma. From a point 1 unit to the left of the right-hand side of the chart, a line was drawn parallel to the straight-line portion of the curve. The point of inter-



METHOD OF DERIVING GAMMA FROM THE H & D CURVE

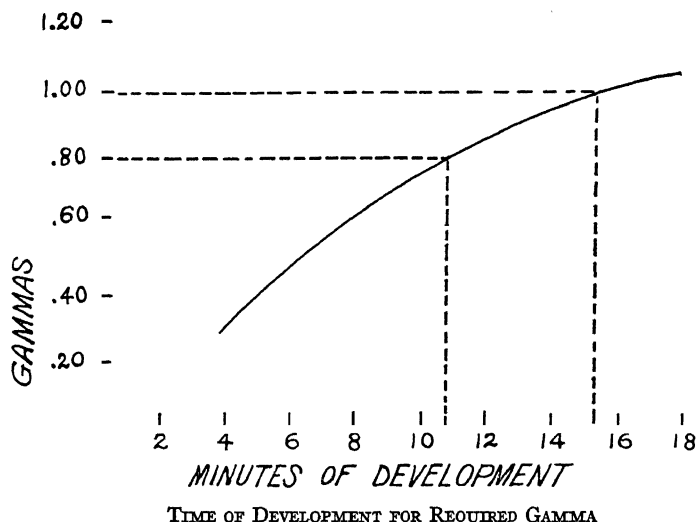
section of this line with the right-hand side of the chart gives a direct reading of gamma if the density scale from the left has been duplicated upon the right-hand side of the chart.

Gamma infinity (γ^∞) is the maximum slope to which an emulsion can be developed. It varies greatly with different emulsions, and is useful in determining to what practical extent emulsions can be forced in development. Development beyond gamma infinity decreases contrast on account of the attendant development of fog, the effect of which is proportionately greater upon the lower densities than it is upon the higher.

The gamma of a negative exposed under other than laboratory conditions cannot be measured, because it is impossible to know the exact strength of

light that resulted in any given density. But if an emulsion, after standardized exposure, is developed to a certain gamma, that same gamma can be duplicated upon the same emulsion, however exposed, by identical development.

TIME-GAMMA CURVE.—If an emulsion exposed under a step-tablet is cut into strips and each strip developed for a different time, and the gamma for each time of development ascertained and plotted against the corresponding time of development, the *time-gamma* curve thus obtained can be made to



show the time necessary to develop to any desired gamma. On the chart, a line parallel to the time-of-development base line, is projected from any desired gamma mark until it intersects the time-gamma curve. A perpendicular dropped from this point will intersect the time of development scale at a point that shows the time of development necessary to produce that gamma. Conversely, a line from any time of development will show the resulting gamma.

DEVELOPMENT BY INSPECTION.—Negatives were at first developed by inspection under a safelight, the operator judging by experience when to stop development. The work was facilitated by the abundance of yellow light which could be safely used with the early plates, which were so large that detail could be plainly seen. Local manipulation was frequently and successfully resorted to. Plates were lifted from the developer and inserted for a time in a tray of water where shadow detail would build up faster than the highlights while the developer in the emulsion was being exhausted, after which the plate was returned to the original solution for further development. This treatment softened the gradations of what would otherwise have been a harsh negative. While in the water, local parts could be strengthened by the

application of developer by a brush or on a pledget of cotton. Development was stopped locally by painting with glycerin, or bromide of potassium solution. Plates were developed to a high gamma to make them suitable for the printing processes then in vogue, and after considerable practice the correct development could be quite accurately determined by the appearance of the highlights from the back of the plate. With increased sensitivity of emulsions, the darkroom light had to be changed, first to ruby, and then to green, and the decreased illumination made observation more difficult. This situation is partly met by desensitizing the emulsion before development so that more light can be used, but the use of progressively smaller sizes of negatives has made it difficult, and in many cases impossible, to see detail. At best, inspection is an unreliable means of development, depending absolutely upon the judgment and experience of the operator, and it has been generally displaced by more scientific methods.

FACTORIAL DEVELOPMENT. — This method of development, formulated by Alfred Watkins in 1894, depends upon the fact that, with normal exposure, the time of appearance of the first details of the image bears a fixed relationship to the total time required for a negative to reach a certain degree of development. The *Watkins factor*, or the *arithmetical coefficient of development*, as it is variously called, by which the time of appearance is multiplied to ascertain the total developing time, varies with different developing agents. It is not affected by different emulsions (except a few which contain an excess of iodide) nor, within reasonable limits, by the temperature or the dilution of the developer (except for amidol and pyro), if they are kept constant during development. Developers containing ammonia cannot be used because it constantly escapes from a solution, whose activity is thereby changed. In noting the appearance of the image, parts that are obviously greatly overexposed, like strong lights, or bright patches of sky in an otherwise normal landscape, should be disregarded. Factorial development can be used only if the exposure has been quite nearly correct. With overexposure the highlights flash too soon, resulting in underdevelopment; with underexposure the time of the first appearance is retarded, resulting in overdevelopment. The factor relationship is upset and new factors must be determined if the emulsion is wet before development, and this includes the use of desensitization. With panchromatic emulsions, sufficient light cannot be used without desensitization to accurately determine the time of appearance without risk of fogging the negatives. Faulty eyesight and differences in the adaptability of different eyes to safelights, also introduce errors in noting the time of appearance.

With all its limitations, factorial development still has many useful applications. It is the only feasible method by which a person without special laboratory facilities can make satisfactory comparisons between different emulsions, and it is also convenient for people who occasionally use different kinds of emulsions with which they have had little experience.

Published factors for different developers are usually arbitrary, seldom stating the degree of contrast that they furnish, so that for practical use, factors must be worked out experimentally to suit individual needs. The following list gives some of the more commonly accepted factors, which must be considered approximations only, but may be useful as a basis for trial.

Hydroquinone	5
Pyro	4-18
Glycin (with soda carbonate)	8
Glycin (with potassium carbonate)	12
Rodinal	30
Amidol	18
Metol	30

In general, the factor depends upon the reducing agent alone, and remains constant with different concentrations of alkali and different amounts of dilution. Pyro is an exception to this rule, and its factor also varies with the amount of bromide used, so that any pyro factor is good only for the specific formula upon which it is calculated. The same is true of amidol, for which the factor varies with the amount of dilution.

For developers which contain more than one reducing agent, the factor is found to a very close approximation, by multiplying the number of parts of each developing agent by its factor, adding these together, and dividing by the total number of parts. Thus, from the above table, the factor for a formula containing 2 parts of metol and 3 parts of hydroquinone would be found as follows:

$$\frac{(2 \times 30) + (3 \times 5)}{5} = 15$$

TIME AND TEMPERATURE DEVELOPMENT. — The activity of all developers increases with the temperature, and best results are uniformly obtained by development for a fixed time, varying with the temperature, which experience has shown will produce a desired gamma on the negative. The work may be done in total darkness, which is the only way to eliminate danger of fog on the fastest panchromatic emulsions, and the result does not depend upon acquired skill in judging densities on the negative, nor in noting the time of appearance of the image.

The time of development to a given gamma depends upon the nature of the emulsion, the reducing energy of the developer, and the temperature at which it is used. This time can be found experimentally (see page 79) if it is not stated by the manufacturer. Different developing times may be required for the same emulsion depending upon whether it is coated upon glass, cut film, rollfilm, or filmpack. Filmpacks often require more time than rollfilms on account of special treatment that they have received to prevent abrasion, but this is not always true.

The temperature of the developer must be kept constant during the time of development. Solutions should be allowed to stand before use until they take on the temperature of the workroom, at which point they will remain constant. If the temperature of the workroom cannot be controlled within desirable limits, the tank or tray containing the developer may be surrounded by a water bath which has been brought to the correct temperature by any convenient means such as hot or cold water, ice, an immersion heater, or an electric grid. Always available, a means of cooling a water bath in a dark-room is by the addition of hypo, which will quickly bring the temperature down many degrees, but great care must be exercised to prevent any of it reaching and contaminating the developer. The bulk of the bath must be so large that its temperature will not change appreciably during the time of development. Ice should not be added directly to a developer because its melting will dilute the solution to an unknown degree, but it may be used in a rubber bag suspended in the developer.

DILUTION OF DEVELOPER. — Slight dilution of the developer gives identical images if the time of development has been properly compensated. The time is not directly proportional to the dilution except when using glycin, which does not oxidize in air. With all other developers, the reducing agent is oxidized by the air in the greater amount of water to such an extent that development takes longer than would be calculated by direct proportion to the amount of dilution. With very great dilution, the character of the image is changed. Shadows are fully developed before highlights attain their greatest density, so that a degree of dilution that necessitates development for an hour or more is often used to develop underexposed negatives, or to obtain soft gradation in negatives of contrasty subjects. The tendency to fog increases with the amount of dilution of the developer.

TEMPERATURE COEFFICIENT. — In order to develop negatives to a constant gamma at different temperatures, it is necessary to know the rate at which changes of temperature affect the performance of the developer. The temperature (or thermal) coefficient of a developer is the factor by which the time of development at a given temperature must be multiplied to give identical development at 10° lower Centigrade (18° F.). This ratio varies with different developers, but is practically constant for different emulsions. It is found by developing two identical exposures in the same developer at different temperatures and timing the first appearance of the image on each, as the total developing time will be proportionate to the time of appearance. The temperature coefficient is then found by the following equation:

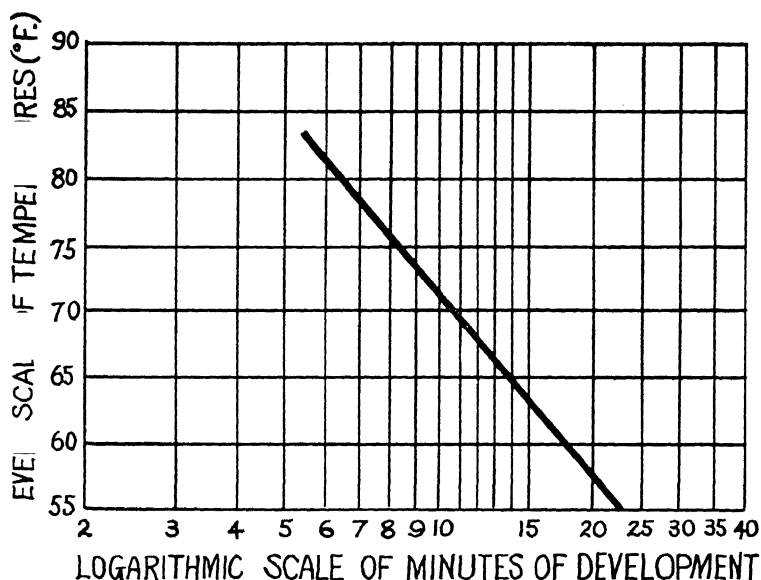
$$\text{Log of Temperature Coefficient} = \frac{(\log T_1 - \log T_2) \times 10}{t_1 - t_2}$$

where T_1 and T_2 are the times of appearance of the image, and t_1 and t_2 the temperatures used.

The temperature coefficients of some of the commonly used developers are:

Metol	1.3
Paraminophenol	1.5
Ferrous oxalate	1.7
Pyro	1.9
Hydroquinone	2.5

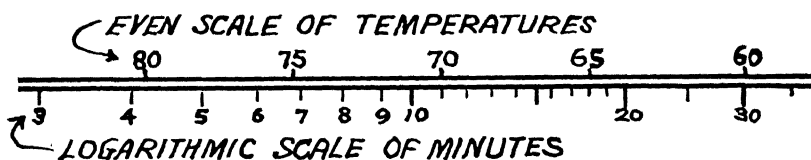
If the times of development for a constant gamma at two temperatures for a given emulsion have been found, the time of development at any other temperature can be found by plotting these points on a log scale of development



TIME AND TEMPERATURE CHART FOR D-76 DEVELOPER ON PANATOMIC X, 35 MM FILM

time against an evenly-spaced scale of temperatures. The projection of a straight line through these two points will indicate upon the chart the developing time at any temperature.

The same result may be obtained by using the logarithmic scale upon a slide rule. This method, as well as the preceding one, is based upon the fact pointed out by C. B. Neblette that the time of development for a given gamma progresses logarithmically. Lay out an even scale of temperatures so gradu-



TIME AND TEMPERATURE SCALE FOR DEVELOPMENT

ated that two different temperatures can be placed against the known time of development at those temperatures on the logarithmic scale, and the correct time of development to produce the same gamma at any temperature can be read from the logarithmic scale.

With a developer containing two developing agents, the temperature coefficient operates only through a limited range of temperature, as each part of the developer in effect retains its own coefficient and the proportion of the developing done by each varies at different temperatures, but with metol-hydroquinone the variation at ordinary working temperatures is negligible, as is shown on the accompanying chart for D-76.

AGITATION. — As agitation increases the speed of development, it is necessary that the amount of agitation be constant to produce identical results. Continuous agitation may increase the speed of development as much as 20 per cent over stagnant development. Agitation is necessary because the developer in use picks up bromide and oxidation products from the emulsion, and these products are more concentrated about the high lights where development is most active. They tend to retard development in adjacent areas, and in horizontal development give rise to *Mackie lines*, surrounding the strongly lighted portions with lighter borders, giving them a silhouette effect. In vertical development, these products flow down over the emulsion from the most strongly exposed parts and retard the development of the parts over which they pass, causing streaks. Without agitation, bromide and oxidation products, being heavier than the developer, tend to settle to the bottom of a tank and slow up development on the lower part of negatives if they are suspended vertically.

With pyro, best results are secured with continuous agitation, but with other developers intermittent agitation usually suffices. If the total time of development is divided into four equal parts and agitation supplied at those intervals, it is usually sufficient. To be quite efficient, agitation should be in more than one direction, and it is good practice to lift each negative entirely out of the developer and immediately replace it each time it is agitated.

DESENSITIZING. — Desensitizers are substances, usually dyestuffs, that reduce the sensitivity of photographic emulsions to such an extent that they can be developed in a bright light without danger of fog, although most of them do not render the emulsion entirely insensitive to light. Interest in this subject began with Carey-Lea in 1877, but it was not until Lüppo-Cramer in 1920 discovered the desensitizing properties of phenosafranine, that the process became practical.

Most desensitizers may be used either as a preliminary bath, or by addition to the developer. Usually 2 or 3 minutes are sufficient for desensitizing in a preliminary bath, which should be done under a safe light or preferably in total darkness, especially for panchromatic emulsions, to avoid fog. Partial or total destruction of the latent image will take place if the desensitized

emulsion is exposed to yellow, orange, or red light before development begins, or if several hours elapse between desensitizing and development. When the desensitizer is added to the developer, the emulsion should not be exposed to bright light until after 3 or 4 minutes.

Mercuric cyanide, an inorganic desensitizer, cannot be used as a forebath, but must be added to the developer in the ratio of 1 part to 3000 parts of the developer. It is not suitable for use with pyro.

Phenosafranine is used as a preliminary bath in the ratio of 1 to 2000, or in the developer in the proportion of 1 to 5000. It stains the gelatin, but the stain does not affect the printing quality of the negative. The stain can be removed by bathing the negative for a few minutes, after washing, in a 5 per cent solution of hydrosulphite. Phenosafranine does not reduce the sensitivity enough to permit its use with panchromatic emulsions of high color sensitivity.

Pinakryptol green is usually used as a preliminary bath at a concentration of 1 to 10,000, for a period of 2 minutes. Greater concentration, or more time, are likely to produce fog and deterioration of the latent image. Pinakryptol green is sometimes added to developers, but is likely to be precipitated in developers containing hydroquinone if used at a concentration greater than 1 to 50,000.

Pinakryptol yellow is used as a preliminary bath in the ratio of 1 to 2000. It cannot be used in a developer because it is destroyed by sodium sulphite. As it causes no stain it is particularly adaptable for use with color plates or films. It is an extremely efficient and clean-working desensitizer and gives little or no chemical fog, although it does cause slight reduction of the density of the image.

Basic scarlet N is used as a preliminary bath at a strength of 1 to 5000. It is less efficient than the pinakryptols, but has less tendency to fog, and is non-staining.

The investigations of R. Freund in 1908, followed by the work of F. F. Renwick in 1920, showed that if an emulsion were immersed for several minutes in

Water	20 oz.
Potassium iodide	90 gr.
Sodium sulphite	90 gr.
Potassium sulphocyanide	260 gr.

and then rinsed, it could be developed even in sunlight in an ordinary diamino-phenol developer freshly compounded with sodium carbonate.

FINE-GRAIN DEVELOPMENT.—While there is considerable difference in the size of the silver grains in different emulsions, none of them individually are large enough to cause trouble in photographic work. The mottled effect at great enlargements, noticeable especially in the lighter tones of a photograph, are occasioned by the clumping together of grains during development.

In an ordinary photographic emulsion there are about six layers of these grains, and while they are very evenly distributed in the emulsion during manufacture, they have a tendency during development to form themselves into groups as though they had mutual attraction for each other. Individual grain size varies quite generally with the speed of the emulsion, the faster emulsions having larger grains. Naturally the effect of clumping is more noticeable in proportion as the grains are larger, so the trouble is greater with fast emulsions than with slow, and "fine-grain" emulsions gain their immunity at a sacrifice of speed.

The first interest in fine grain was manifested by astronomers and other scientists between 1904 and 1920, who were interested in getting the utmost resolving power out of photographic emulsions. During the 1920's the motion-picture industry became greatly concerned with the problem; and after 1930 the enormous increase in the use of miniature cameras and high-speed films, and the need of gigantic enlargements for photo-murals, made it acute.

Physical development which had been known since its discovery by Young in 1858 to give fine grain, was further exploited by Sterry and Neuhauss in 1898, but it required five times normal exposure and development for about 2 hours, so that it was of little practical use until the contributions of Lumière and Seyewetz between 1911 and 1925 and of Lüppo-Cramer in 1919 culminated in the work of Dr. Allan F. Odell in 1933, which resulted in a thoroughly practical process without loss of emulsion speed (see page 91). Physical development gives an image sufficiently fine-grained for the needs of many workers. If it is inclined to be somewhat erratic in operation it is usually on account of impurities in the chemicals used, or for lack of chemical cleanliness of the utensils.

In 1927 the Eastman Kodak Company, as a result of the researches of Capstaff and Purdy, announced its famous fine-grain formula, D-76 (see page 58), which was the prototype of many other developers working on the same principle of low alkalinity and a very high concentration of sodium sulphite which has a solvent action on the silver grains, reducing their size and minimizing clumping. During development, the image is also probably somewhat augmented by a form of physical development, the silver bromide dissolved by the great amount of sulphite being converted into a silver salt from which silver is liberated by the developer and deposited upon the image. This type of developer gives negatives that are sufficiently fine-grained for many purposes. It is clean-working, long-lived, utilizes the maximum film speed, and even with coarse-grained, high-speed emulsions gives enlargements up to about ten diameters without troublesome grain.

Paraphenylenediamine was known from the earliest days of the use of the coal-tar derivatives, its principal use being as a dye for fur, but it was little used as a developer on account of its low reduction potential, and because it was poisonous to many people (see page 62). As early as 1904, attention

had been called to the fine-grained image that it produced, but by any formulas known at the time it resulted in great loss of emulsion speed, excessive development time, and at best a thin, flat negative. In 1928 workers applied the principle of a high concentration of sodium sulphite to paraphenylenediamine, producing very fine-grained negatives with an hour's development, but with a prohibitive loss of emulsion speed. In 1933, by the addition of tri-sodium phosphate, to which attention had been called by the Lumière brothers and Seyewetz in 1895, and metol, the developing time was reduced to 7 minutes. In the same year, Purdon announced the following formula combining paraphenylenediamine with glycine, which was the first of many formulas along that line.

PURDON'S FORMULA

Sodium sulphite	30 g
Paraphenylenediamine	5 g
Glycine	5 g
Water	400 cc

This required only normal exposure, and maximum contrast was obtained by 30 minutes' development at 65° F.

In 1934 Dr. Sease of the DuPont Film Laboratories announced a group of four formulas all of which contained the same proportions of paraphenylenediamine and sodium sulphite, but with glycine varying from none at all to 12 grams per 1000 cc (see page 63). The fineness of grain is in indirect ratio to the amount of glycine. With no glycine, or with amounts up to 2 grams per 1000 cc, three to four times normal exposure is required for fast films, although little or no increase in exposure is needed with the slower, fine-grained films. With 2 or more grams of glycine per 1000 cc, the exposure is cut to about two times normal, but with graininess increasing with the amount of glycine used. While these developers immediately became very popular, the loss of speed in the emulsion was a great handicap to their use.

Compromise developers were devised to give grain as fine as possible with no loss or with even a slight gain in speed, to take care of unavoidable or inadvertent underexposure. For this purpose, pyro or metol was added to the other developing agents. Of these developers, the Edwal 12 is deservedly one of the most popular.

EDWAL 12

Water (distilled)	32 oz.	1000 cc
Metol	90 gr.	6 g
Sodium sulphite	3 oz.	90 g
Paraphenylenediamine (pure base)	150 gr.	10 g
Glycine	75 gr.	5 g

To give finer grain, the formula Edwal 20 substituted 75 grains (5 g) of Gradol, a product of the Edwal laboratories, for the metol in the above

formula. This gives a finely graduated negative, but the emulsion speed is reduced to about 70 per cent of normal.

Morris Germain has suggested a very satisfactory developer for enlargements up to ten diameters on fast film and up to twenty diameters on fine-grained films.

GERMAIN FINE-GRAIN DEVELOPER

Water	32 oz.	1000 cc
Metol	$\frac{1}{4}$ oz.	7 g
Sodium sulphite	$2\frac{1}{2}$ oz.	70 g
Paraphenylenediamene (base)	$\frac{1}{4}$ oz.	7 g
Glycin	$\frac{1}{4}$ oz.	7 g

For a replenisher, use the same formula.

This developer has excellent keeping qualities and maintains its energy almost indefinitely if the solution is kept up to its original bulk by the addition of fresh developer compounded according to the same formula. It does not require additional exposure.

In 1936 and two subsequent years, Harry Champlin furnished some formulas designed to give the utmost in fine grain and at the same time increase the speed of some films. Of these formulas, the No. 15 became very popular. It has good keeping qualities, does not require extra exposure, and in the case of some of the faster films is even said to increase their speed.

CHAMPLIN 15

Water	20 oz.	1000 cc
Rubinol or Pyro	32 gr.	3.5 g
Sodium sulphite	$1\frac{1}{2}$ oz.	60 g
Acid benzoic	12 gr.	1.2 g
Acid salicylic	4 gr.	0.5 g
Acid boric	25 gr.	2.5 g
Acid digallic (Tannic)	9 gr.	1 g
Glycin	$\frac{1}{4}$ oz.	11.5 g
Paraphenylenediamine (base)	$\frac{1}{4}$ oz.	11.5 g
Alcohol Iso Propyl 97 per cent	1 oz.	50 cc
Nickel ammonium sulphate	10 gr.	1 g

Dissolve the chemicals in the order given. Dissolve the paraphenylene separately in a small quantity of water (deducting this amount from the original 20 ounces) which has been heated to about 120° F. After this hot solution has been added to the developer, wait until the whole cools to 70° F. before adding the nickel ammonium sulphate which has been previously dissolved in 1 ounce of cold water. Although this is added very slowly to the developer, a precipitate will probably form and settle to the bottom of the container. This precipitate must be filtered out before using the developer. Use a filter paper, as cloth or absorbent cotton will not filter it satisfactorily.

Thirty-two ounces of this developer will develop ten rolls of 35 mm film

but the time of development will have to be increased by about 2 minutes for each succeeding film.

Compensating developers are devised to allow development to be carried far enough to bring out the shadow detail while the highlights do not build up unprintable density.

METOL COMPENSATING DEVELOPER (Mimosa)

Metol	125 gr.	14 g
Sodium sulphite	615 gr.	70 g
Potassium bromide, 10 per cent solution ..	30 minims	3 cc
Water to make	20 oz.	1000 cc

Development will take 8 to 10 minutes.

PARAPHENYLENEDIAMINE COMPENSATING DEVELOPER

Sodium sulphite	525 gr.	120 g
Metol	44 gr.	5 g
Paraphenylenediamine	88 gr.	10 g
Sodium phosphate (tribasic)	31 gr.	3.5 g
Potassium bromide	9 gr.	1 g
Water	34 oz.	1000 cc

Windisch proposes the use of *orthophenylenediamine* in the following developer which gives a very fine grain, but with a loss of half the emulsion speed.

ORTHOPHENYLENEDIAMINE DEVELOPER (Windisch 665)

Water (boiled)	21 oz.	600 cc
Sodium sulphite	2 oz.	55 g
Orthophenylenediamine	114 gr.	7 g
Metol	114 gr.	7 g
Potassium metabisulphite	98 gr.	6 g

Dissolve the chemicals separately in the water after it has become lukewarm. Mix the developing agents and then add the sulphite and then the bisulphite and stir until clear.

In 1938 the Eastman Kodak Co., following the researches of Crabtree and Henn, published the fine-grain formula DK-20, which makes use of potassium thiocyanate for its solvent action upon silver halides, and of the proprietary alkali, Kodalk, which has properties lying between those of carbonate and borax.

KODALK FINE-GRAIN DEVELOPER (Eastman DK-20)

Water (about 125° F.)	96 oz.	750 cc
Elon	290 gr.	5 g
Sodium sulphite	13½ oz.	100 g
Kodalk	116 gr.	2 g
Potassium sulphocyanate (thiocyanate) .	58 gr.	1 g
Potassium bromide	29 gr.	0.5 g
Cold water to make	128 oz.	1000 cc

REPLENISHER SOLUTION DK-20R (for DK-20)

Water (about 125° F.)	96 oz.	750 cc
Elon	1 oz.	7.5 g
Sodium sulphite	13½ oz.	100 g
Kodalk	2 oz., 290 gr.	20 g
Potassium sulphocyanate (thiocyanate)	290 gr.	5 g
Potassium bromide	58 gr.	1 g
Cold water to make	128 oz.	1000 cc

Add to the tank as necessary to maintain the volume constant.

DK-20 results in a loss of 35 per cent in emulsion speed as compared with D-76, but gives only half the amount of graininess. It is recommended for use at 65° F., at which it gives the finest grain compatible with a minimum loss of emulsion speed. Higher emulsion speeds are obtained by developing at higher temperatures, up to 80° F., but with a corresponding increase in graininess. Finer grain can be obtained by increasing the thiocyanate content up to 1.5 or 2 grams per liter, by lowering the temperature, and by using less Kodalk, but always with a proportionate loss of emulsion speed.

It is generally assumed that the principal factors conducive to fine grain are minimum but sufficient exposure; development to a low gamma; a high concentration of sodium sulphite and a low alkalinity in the developer; processing at a low temperature; and rapid drying without artificial heat.

The tendency of grains to clump is facilitated by softening or disrupting the gelatin, which occurs at high temperatures or with an excess of alkali. This action has a longer time to continue if the drying is prolonged.

Developers of low reduction potential do not penetrate deeply into the emulsion, and most of them probably combine some physical development with their chemical action. Sodium sulphite in large concentrations has a solvent action upon the silver grains, lessening their size. Mild alkalis like borax have a less disruptive action upon the gelatin than do the carbonates.

Graininess increases with the density of the silver deposit on the negative, and hence is increased by overexposure which increases the over-all density of the negative, and by long development which increases it locally.

The finest grain cannot be secured by development that will yield the utmost in emulsion speed, and most fine-grain developers are a compromise between these two desiderata.

FERROUS OXALATE, $\text{FeC}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$, was one of the first developers used for dry plates, it having been introduced by Eder in 1879. On account of the care needed in preparing it, and because it requires about four times normal exposure, it has been almost altogether supplanted by organic developers over which it has no advantages for ordinary use. But it is still used in scientific work that demands photometric measurements of great accuracy because it is practically the only developer that gives no trace of stain or fog. It also has advantages in the redevelopment processes of intensification.

FERROUS OXALATE DEVELOPER

25 per cent solution ferrous sulphate	1 part
25 per cent solution <i>neutral</i> potassium oxalate	3 parts

The ferrous sulphate solution oxidizes very rapidly on exposure to air, and should be kept in small bottles completely filled. The two solutions should be mixed, with constant stirring, only at the time of use. In mixing, the sulphate should be added to the oxalate, as an insoluble iron salt will be precipitated if there is not an excess of oxalate to dissolve it.

This developer can be used without potassium bromide, but the addition of about 4 grains of potassium bromide to 10 ounces of the developer will correct overexposure, to a limited extent. A few drops of a 1 to 1000 solution of hypo has a great accelerating effect on this developer, but anything more than a minute quantity of hypo produces a heavy fog. A white precipitate of calcium oxalate which may be deposited upon the negative when it is placed in the hypo, can be removed during washing by placing the negative for a few moments in a 1 to 200 solution of hydrochloric acid, and then continuing the washing.

PHYSICAL DEVELOPMENT. — In this process a silver salt is combined with a reducing agent in the developer, and the action is to precipitate silver on the latent image, rather than to reduce the silver in the emulsion as is done by chemical development. It results in a very fine-grained image, regardless of the size of grains in the emulsion. The process is slow, it requires extraordinary care and cleanliness, and there is little control over the contrast of the negative. Tanks should be of glass, bakelite, stainless steel, or chromium plate, as other metals attract the silver out of the solution and become plated with it, weakening the developer. Tanks should be washed with dilute nitric acid and rinsed before use, to make them chemically clean. The process of Dr. Odell (see page 86) is the one most generally used, and is as follows:

FOREBATH

Potassium iodide	80 gr.	5 g
Sodium sulphite	195 gr.	12.5 g
Water to make	16 oz.	500 cc

After 3 or 4 minutes in the forebath, the negative is rinsed in two changes of water, or for 30 seconds in running water. This forebath should be made with distilled water, and filtered before use. It can be used six or seven times if filtered back into a brown bottle after use.

The stock solution for the developer consists of:

PHYSICAL DEVELOPER (ODELL)

Sodium sulphite	1 oz.	30 g
Silver nitrate (crystals)	120 gr.	8 g
Hypo crystals	2 oz., 300 gr.	80 g
Water to make	16 oz.	500 cc

Dissolve the sulphite in 8 ounces (250 cc) of water, and the silver nitrate in 7 ounces (200 cc). Add the silver solution to the sulphite, stirring until completely dissolved, then add the hypo and stir until solution is complete, and then add water to bring the bulk up to the specified amount. Filter into a chemically clean storage bottle.

For use, mix just before using:

Silver stock solution	3½ oz.	100 cc
Water to make	16 oz.	500 cc
Amidol	12 gr.	0.75 g

Stir the amidol until completely dissolved. Use distilled water throughout. The working solution can be used only once. Develop for 30 minutes at 65° F., with quite constant agitation. After development, rinse briefly in water and remove any scum with wet cotton. Fix in the usual acid-hardening hypo bath, and wash.

It is of interest that by physical development negatives may be developed after fixation, or that by using suitable proportions of hypo in the developer, development and fixation may be carried on simultaneously.

DEVELOPMENT AFTER FIXATION. — That the latent image may be physically developed after first fixing out the silver salts, was noted by Young in 1858 in connection with collodion plates, and by Kogelmann in 1894 in connection with gelatino-bromide emulsions. The most practical method is that suggested by Lumière and Seyewetz in 1924. The emulsion is given an ample exposure and then fixed in a 30 per cent hypo bath to which has been added 100 minims (10 cc) of ammonia that tests 22° B. Fixation of not more than 5 minutes, should be followed by washing in several changes of water made alkaline with ammonia, after which development may be carried out in full light. Distilled water and chemical cleanliness of utensils are important, and tanks or trays should be of glass, bakelite, stainless steel, or chromium plate so that the silver will not deposit upon them. The developer is as follows:

STOCK SOLUTIONS

Solution A

Sodium sulphite	3 oz., 270 gr.	180 g
Silver nitrate (10 per cent solution)	1½ oz.	75 cc
Water to make	20 oz.	1000 cc

Solution B

Sodium sulphite	175 gr.	20 g
Paraphenylenediamine (base)	175 gr.	20 g
Water to make	20 oz.	1000 cc

If mercury is preferred to silver, 80 grains (9 g) of mercuric bromide may be substituted for the silver in solution A, and the paraphenylenediamine of solution B replaced weight for weight with metol.

Development is by inspection, and takes several hours. The solution is exhausted in use before the negative is developed, and must be drawn off and

replaced by fresh at hourly intervals. Development can be prolonged until very high gammas are reached, or the negative may be developed less and afterwards intensified.

COMBINED DEVELOPING AND FIXING has been a subject of investigation since its possibility was shown by Richmond in 1889. Dr. Mees in 1921 noted that many emulsions have to be greatly overexposed if they are to be subjected to this treatment, and that the two processes are not equally influenced by changes in temperature, fixation being retarded by cold and accelerated by heat more than development is. Lumière and Seyewetz in 1924 recommended the following bath.

Sodium sulphite	350 gr.	40 g
Amidol	45 gr.	5 g
Sodium phosphate (tribasic)	175 gr.	20 g
Hypo	$\frac{1}{2}$ oz.	25 g
Water to make	20 oz.	1000 cc

The process is completed in 15 or 20 minutes at a temperature between 60° F. and 65° F. The solution can be used only once.

The difficulty of maintaining an even balance between the two processes at different temperatures, and the liability of fog and stain on the negatives, make this method of development of little practical worth.

TROPICAL DEVELOPMENT. — Excessive heat and humidity during processing causes undue swelling of the gelatin which is likely to result in frilling, reticulation, melting, separating from the base, and fog and stain. Swelling is minimized by a hardening forebath, or by combining with the developer agents that prevent swelling, and following development with a hardening process.

Formalin (40 per cent formaldehyde) in alkaline solution or with the addition of sodium sulphate, can be used as a forebath, but if used at over a 5 per cent concentration it will cause fog, and at this concentration its action is slow.

Pyro and pyrocatechin have a tanning action upon gelatin, and metol-hydroquinone with less than the usual amount of sodium sulphite has a hardening action, but swelling of the gelatin during development is usually controlled by using a concentrated developer and adding some inert material such as sodium or potassium sulphate, glucose, or sugar to increase the concentration. Sodium sulphate definitely retards the speed of development, partially offsetting the natural acceleration caused by the high temperature. Development should be within a few days of exposure, as the latent image is liable to deteriorate under the combined influences of heat and moisture. When gelatin is swollen, sudden changes in temperature should be avoided. It is better to use all solutions at room temperature, however hot, than to have some of them much cooler than others. With the use of a concentrated developer, immediately followed by an efficient hardening bath before

fixing, emulsions can be developed in temperatures up to 90° F. in the following developer.

TROPICAL DEVELOPER (Eastman DK-15)

Water (about 125° F.)	24 oz.	750 cc
Elon	82 gr.	5.7 g
Sodium sulphite	3 oz.	90 g
Kodalk	$\frac{3}{4}$ oz.	22.5 g
Potassium bromide	27 gr.	1.9 g
Sodium sulphate	1½ oz.	45 g
Cold water to make	32 oz.	1000 cc

If it is desired to use sodium sulphate crystals instead of desiccated sulphate, use 3½ ounces per 32 ounces of developer (105 g per 1000 cc).

At normal temperatures of 65° F. to 75° F. (18° C. to 24° C.), development will be more rapid if the sodium sulphate is omitted, but it should always be used when working above 75° F. (24° C.).

Average time for tank development *without* the sulphate is 5 to 7 minutes and *with* the sulphate 9 to 12 minutes at 65° F. (18° C.) in the fresh developer according to the contrast desired. Develop about 20 per cent less for tray use.

By increasing or decreasing the quantity of Kodalk in the formula, it is possible (a) to increase or decrease the contrast obtained in a given time of development or (b) to decrease or increase the time of development without affecting the contrast. Prolonging the development time, however, is *very undesirable*, as excessive swelling and softening of the gelatin will occur.

Approximate times of development at 80° F. to 90° F. (26.5° C. to 32° C.) are from 5 minutes at 80° F. (26.5° C.) to 2½ minutes at 90° F. (32° C.).

After development, rinse the films not more than 1 second in water (omit water rinse above 85° F.) (29.5° C.), and immerse directly in the Tropical Hardener (Formula SB-4) for 3 minutes. Then fix in regular acid-alum fixing bath for at least 10 minutes and wash for 10 to 15 minutes in water not over 95° F. (35° C.).

TROPICAL HARDENING BATH (Eastman SB-4)

(For use at 75° to 90° F. (24° to 32° C.))

Water	32 oz.	1000 cc
Potassium chrome alum	1 oz.	30 g
Sodium sulphate	2 oz.	60 g

Agitate the negatives for 30 to 45 seconds when first immersing in the hardening bath, or streakiness will result. Leave them in the bath for at least 3 minutes between development and fixation. This bath will process about 1600 square inches of film, after which it should be replaced, or scum markings will result. When the violet-blue color of the bath turns to a yellowish green, it is a sign of exhaustion.

The Eastman formula D-76 (page 58) can be used at temperatures above

75° F. by adding 1½ ounces per quart (45 g per 1000 cc) of desiccated sodium sulphate, and increasing development time by one-third. This gives low graininess and maximum shadow detail.

Up to 80° F., a slightly acidulated amidol developer may be used without any special precaution, as gelatin swells only very slightly in acid baths. According to L. J. Brunel, the following amidol developer may be used up to 95° F.

TROPICAL AMIDOL DEVELOPER

Sodium sulphite	260 gr.	30 g
Potassium metabisulphite	90 gr.	10 g
Amidol	45 gr.	5 g
Potassium bromide	45 gr.	5 g
Lactic acid (officinal)	50 minims	5 cc
Sodium sulphate (crystal)	2 oz.	100 g
Water to make	20 oz.	1000 cc

Sodium sulphate cannot be depended upon to prevent excessive swelling of the gelatin at temperatures above 95° F., and at higher temperatures part of the water with which the developer is mixed must be replaced with alcohol.

STAIN IMAGES.—Stain images that are formed with the silver image during development, especially those occurring with pyro, are sometimes deliberately sought and utilized. They often give the same effect as prolonged development, or certain forms of intensification, and are particularly useful on very thin negatives resulting from underexposure. In extreme cases, with very dense negatives, the silver image is sometimes completely bleached in Farmer's reducer, and printing is done from the remaining stain image, which is very fine grained. There is always a general stain on a negative in connection with an image stain. An old, or oxidized developer may give the general stain without the image stain because the developer has been so largely converted to oxidation products that it will not give an image stain. A developer, like the following, specially compounded to give the maximum amount of stain, should be used if stain is wanted.

PYRO STAIN DEVELOPER (Eastman SD-1)

Water (about 125° F.)	16 oz.	500 cc
Sodium sulphite	20 gr.	1.4 g
Pyro	40 gr.	2.8 g
Sodium carbonate	75 gr.	5.3 g
Water to make	32 oz.	1000 cc

Develop for 7 minutes at 65° F. (18° C.) in a shallow tray, rinse and fix in a plain hypo bath.

REVERSAL.—When a negative has been developed but not fixed, the metallic silver forming the image can be bleached away by an agent that does not attack the undeveloped bromide of silver remaining in the emulsion. This remaining silver bromide can then be given a general exposure to white

light and developed into a positive image. While this treatment can be given to any emulsion, results are more or less uncertain except upon films specially made and listed by the manufacturers for this purpose.

After development, the negative is rinsed for 15 or 20 seconds in water and then bleached until the silver image entirely disappears.

PERMANGANATE BLEACH

Water to make	20 oz.	1000 cc
Potassium permanganate	35 gr.	4 g
Water to make	20 oz.	1000 cc
Sulphuric acid (66° Bé.)	3½ oz.	20 cc

It is best to keep the two solutions separate until the time of use. Always pour sulphuric acid into water and never the reverse, or an explosion will occur, which would also happen if the concentrated sulphuric acid were poured on to the permanganate.

After bleaching, the negative is briefly rinsed in water and then cleared for a few minutes in a very dilute solution of sodium bisulphite (1/10 of 1 per cent), and then rinsed again.

A less contrasty result is obtained by bleaching in a weak solution of potassium bichromate with an equal amount of sulphuric acid.

BICHROMATE BLEACH

Potassium bichromate	1 per cent
Sulphuric acid	1 per cent

Rinse, and clear in a 5 per cent solution of sodium sulphite, and rinse again.

After bleaching, the emulsion is exposed to white light and then developed in any non-staining developer, amidol being a common choice. This exposure can conveniently be given after the negative is in the second developer, under the solution, to avoid uneven exposure caused by trails of liquid in the emulsion if exposed in the air.

The exposure may be a very full one, in which case development reduces to metallic silver for the final positive image all the silver bromide remaining in the emulsion. There obviously being nothing left in the emulsion to fix out, washing completes the operation. This is the method used in the mosaic-screen color processes. It works very well for thin emulsions, or for emulsions that have been specially made for reversal. It cannot be used with double-coated emulsions, and with ordinary emulsions there is more silver bromide left in the emulsion than is needed for the positive. With these emulsions, the second exposure must be correct, as the image would be fogged by a prolonged, general exposure to light. In any emulsion there is a difference of speed in the individual grains of silver, and the fastest ones are first exposed, so that when the negative is developed there still remain in the shadows most of the fastest grains, while in the highlights only the slowest grains are left.

A suitable uniform exposure upon this modified emulsion will thus result in an effect similar to different exposures on different parts of it, much as if it had been exposed under the original negative which has been bleached away.

The proper exposure is determined by trial and error, giving first a short exposure known to be insufficient and estimating from the appearance of the image as it develops, how much more exposure is necessary. Additional exposure can be given in several stages during the course of development. After exposure and development are completed, the remaining, unused silver bromide must be removed by fixation as in the usual process of negative making, followed by a final washing.

DIRECT REVERSING FILM. — There are on the market one or more direct *reversing films*, whose characteristic curve shows only the reversal region of overexposure and none of the other regions normally used in negative making. This film becomes entirely black when developed without exposure, and ordinary exposure in a camera results in a positive. The longer the exposure, the lighter the image. This film is used for copying negatives. Development of the film after it has been printed under a negative, results in another negative, making it a very quick and convenient means of obtaining duplicate negatives, especially when many are wanted for printing in gangs. Best results are obtained only by using the developer recommended by the maker of the film.

CHAPTER IV

FIXING, WASHING, AND DRYING NEGATIVES

After development, which reduces part of the silver salts in an emulsion to metallic silver, the unaffected salts that remain must be removed as they would otherwise eventually be acted upon by light and stain the negatives. These salts, not being soluble in water, must first be converted into soluble compounds, and then washed out of the emulsion. The conversion process is somewhat ambiguously called *fixation*, and the permanence of the negative absolutely depends upon the thoroughness with which both it and the subsequent washing are performed. Efficient washing can never compensate for insufficient fixing, because no amount of washing can remove silver salts that have not been made soluble. On the other hand, rendering the salts soluble is of no benefit to the emulsion if they are left in it. It is the combination of both thorough fixing and thorough washing that ensures the permanence of the negative.

THIOSULPHATE OF SODA, "Hypo," $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ (often incorrectly called *hyposulphite* of soda by photographers), is one of the very few substances which will dissolve silver bromide, and on account of its cheapness and efficiency it is the one universally used. Its properties were first discovered by Herschel, son of the astronomer, in 1819, and it was used by J. B. Reade photographically in 1837, although at that time its price was practically prohibitive. While very effective upon bromide and chloride of silver, it is much less so upon iodide of silver, and during the wet-collodion period it was supplanted by cyanide of potassium. But since the advent of gelatino-bromide emulsions, it has been greatly reduced in cost, and is used to the practical exclusion of any other fixing agent.

Hypo is generally used in the crystalline form, as dehydration is complicated and expensive, and offers but slight advantage. Hypo crystals are indicated in all formulas in this book. Hypo is conveniently dissolved by suspending it in a cloth bag in the top of a tank or a wide-mouth jar, allowing the bag to rest near the top in the necessary amount of water. All dirt is thus filtered out, while solution proceeds without attention. Water at 125°F. may be used, as hypo cools the solution considerably while dissolving. No other chemicals should be added to the hypo solution until it has cooled to the temperature at which it will be used.

The action of hypo is quite slow in a 5 per cent solution, but its speed increases with concentration up to 30 per cent for a positive emulsion and 40 per cent for a negative emulsion, and then falls off again until at a concentration of 50 per cent or more it is as slow, or even slower than a 5 per cent

concentration. This is caused by the increased difficulty with which the denser solutions permeate the emulsion. Within the limits mentioned, hypo is equally efficient at any concentration, the only difference being in the amount of time required. As a compromise between convenience and economy, concentrations between 20 per cent and 30 per cent are generally used. For economy, 15 per cent solutions are sometimes used by occasional workers, but in commercial establishments where time is a more important factor, higher concentrations are used. Emulsions should be guarded from white light when fixing at concentrations above 30 per cent, as otherwise slight insoluble compounds are likely to be formed.

The speed of fixation increases with higher temperatures, the rate varying at different concentrations, but this is of little practical importance, and it is advised to use a fixing bath at temperatures between 65° and 70° F., because higher temperatures are likely to precipitate sulphur out of the hypo. The rate of fixation is also increased by agitation.

The actual time of fixation depends upon the strength of the solution; its temperature; amount of agitation; the extent to which the solution has been used; and the nature of the emulsion. Silver chloride fixes faster than bromide, and bromide faster than iodide. Fine-grained emulsions fix faster than coarse-grained one. The rate of fixation is not affected by the degree of swelling of the gelatin, nor by its having been hardened. The action of a fixing bath is progressively slowed down in use on account of the decreasing concentration of hypo, and the restraining action of accumulated alkaline halides.

The time for complete fixation of a negative is as long again as it takes it to "clear," or lose its milky, opalescent appearance. This stage of fixation indicates that about 95 per cent of the un-reduced silver salts have been made soluble. According to the general laws of physical chemistry, a fixing bath dissolves in a given time a constant fraction of the amount of silver bromide that was in the emulsion when that time-interval commenced. If, in a certain time, 95 per cent was fixed, in another equal length of time 95 per cent of the remaining 5 per cent would be fixed. The residue, amounting to no more than $\frac{1}{4}$ of 1 per cent is negligible, although it will be still further slightly reduced by the continuing action of the hypo during the first of the washing.

Alkaline solutions of hypo have no apparent effect upon the silver of a photographic image, but in an acid solution hypo slowly attacks the silver, and if a negative is left in the fixing bath for several hours, there will be a noticeable reduction of the image.

STOP BATHS. — Negatives should be rinsed in water, or placed in an acid stop bath, often called a "short-stop," between developing and fixing, to stop the action of the developer and so that as little developer as possible will be carried over into the fixing bath. It is also sometimes advisable to use a hardening bath at this point.

ACETIC ACID RINSE BATH (Eastman SB-1a)
(For films or plates.)

Water	32 oz.	1000 cc
Acetic acid (28 per cent pure)	4 fluid oz.	128 cc

HARDENER RINSE BATH (Eastman SB-3)
(Use for films or plates, at 65° to 75° F.)

Water	32 oz.	1000 cc
Potassium chrome alum	1 oz.	30 g

Agitate the negatives for several seconds when first immersed in the hardener, and allow them to remain in the solution for 3 to 5 minutes. This bath is especially recommended for hot weather. When its original blue-violet color becomes yellowish-green on account of the sulphite carried over into it from the developer, it will no longer harden the film, and should be replaced.

The following combined acid-hardening stop bath is much used for miniature films, and if followed by the usual acid-hardening fixing bath, makes them so hard as to be practically impervious to scratches.

SHORT-STOP AND HARDENER

Water	16 oz.	500 cc
Chrome alum	145 gr.	10 g
Sodium bisulphite	145 gr.	10 g

Dissolve the chrome alum completely before adding the bisulphite which should then be stirred until completely dissolved. Use at the same temperature as that of the developer. Leave film in the solution for 5 minutes, after agitating it for a few seconds. This bath should be prepared just before use, and discarded after being used once.

PLAIN HYPO. — A plain solution of hypo will dissolve silver halides as efficiently as any more complicated bath, and it is sometimes used when only a few negatives are to be fixed and it is not desired to save the bath for further use. An acid short-stop and hardener should be used. A concentration of 30 to 40 per cent of hypo is advised, and the temperature should be kept not above 65° F. The bath must be discarded after use for a few negatives.

ACID HYPO. — In spite of rinsing and stop baths, some developer is always carried over in the emulsion into a fixing bath. In a plain hypo bath, this soon accumulates in sufficient quantity to oxidize and cause stains. To prolong the life of the bath by preventing this oxidation, sodium sulphite is added, and with it, a weak acid which stimulates its action and also serves the purpose of stopping development immediately, preventing uneven development which would otherwise be caused by the continuing action of the various amounts of developer retained in different parts of the emulsion. A strong acid cannot be used with hypo because it liberates sulphur which attacks the silver of the emulsion, forming silver sulphide and causing stain. A comparatively large volume of a rather weak acid is needed so that there will be a

reserve of acidity without too strong concentration. Substances which contain sulphurous acid can be used without precipitating sulphur, and the ones most commonly used are sodium bisulphite (NaHSO_3), potassium metabisulphite ($\text{K}_2\text{S}_2\text{O}_5$), or sodium sulphite (Na_2SO_3) with acetic acid ($\text{CH}_3\text{-COOH}$). Citric acid ($\text{C}_6\text{H}_8\text{O}_7\text{H}_2\text{O}$) and boric acid (H_3BO_3) are also used.

Sodium bisulphite lye, which contains about 9 ounces of bisulphite in 20 ounces (35° B.) and is commercially obtainable, is often used instead of the dry chemical on account of its purity and constant strength.

SODIUM BISULPHITE FIXING BATH

Hypo	6 oz.	300 g
Sodium bisulphite lye	1 oz.	50 cc
Water to make	20 oz.	1000 cc

SODIUM SULPHITE AND BISULPHITE FIXING BATH

Hypo	8 oz.	250 g
Sodium sulphite	145 gr.	10 g
Sodium bisulphite (dry)	365 gr.	25 g
Water to make	32 oz.	1000 cc

The acidity of this bath can be maintained in use by the addition of suitable amounts of a 25 per cent solution of sodium bisulphite.

POTASSIUM METABISULPHITE FIXING BATH

Hypo	$6\frac{1}{2}$ oz.	400 g
Potassium metabisulphite	$\frac{1}{2}$ oz.	25 g
Water	16 oz.	1000 cc

BORIC ACID FIXING BATH

Hypo	5 oz.	250 g
Boric acid (crystals)	220 gr.	25 g
Water to make	20 oz.	1000 cc

Heat the water to about 125° F., dissolve the hypo in one-half the water and the boric acid in the other half, and do not mix the two solutions until they are cool.

CITRIC ACID FIXING BATH

Hypo	$6\frac{1}{2}$ oz.	400 g
Citric acid	230 gr.	30 g
Sodium sulphite	270 gr.	35 g
Water (125° F.)	16 oz.	1000 cc

Dissolve the hypo in half the water, the acid and sulphite in one-quarter, and when cool mix the solutions and make up to bulk.

ACETIC ACID FIXING BATH

Hypo	5 oz.	250 g
Sodium sulphite	45 gr.	5 g
Acetic acid (glacial)	50 minims	5 cc
Water to make	20 oz.	1000 cc

Dissolve the sulphite in about $3\frac{1}{2}$ ounces (100 cc) of cold water. Dilute the acid about five times and add slowly with constant stirring to the sulphite. Add this mixture slowly to the cool solution of hypo.

Acetic acid is obtainable in two forms. The 99 per cent is called glacial because it freezes at about 60° F., and for this reason care should be taken to store it in a warm place. It is a strong caustic and should not be allowed to come in contact with the skin. Commercial acetic acid (28 per cent) may be used in place of the glacial in the ratio of 3½ to 1. Glacial acetic acid may be nearly enough converted to 28 per cent by diluting 3 parts with 8 parts of water.

Acid fixing baths are satisfactory to use if the temperature is such that it is not necessary to harden the gelatin, or if a hardening bath is used before fixing. Unhardened emulsions must be dried in cool air, without application of heat.

ACID-ALUM-HYPO. — Instead of using a separate hardening bath, potassium alum or chrome alum is usually added to the fixing solution, which must also contain a preservative such as sodium sulphite, and an acid. Acetic acid is the most efficient for use with potassium alum, and sulphuric acid with chrome alum. Sodium bisulphite and potassium metabisulphite are not satisfactory for use with alum because they have not enough reserve acidity to prevent precipitation of aluminum sulphite in the bath. A nice balance must be maintained between the different parts of an acid-hardening fixing bath. Acid liberates sulphur from hypo, forming milk of sulphur, but if there is sufficient sodium sulphite in the solution, it combines with the sulphur to form hypo again. If the sulphur is precipitated, which may be caused by too high a temperature, too strong a concentration of acid, or too little sodium sulphite, the bath must be discarded, as the sulphur can then be re-dissolved only by boiling the solution. If the reserve acidity is not sufficient, aluminum sulphite will be precipitated. A minimum amount of alum is necessary for hardening, while too much will cause film to become brittle.

ACID-HARDENING FIXER (Agfa 201)

<i>Solution 1</i>		
Water (125° F.)	16 oz.	500 cc
Hypo	8 oz.	240 g
<i>Solution 2</i>		
Water (125° F.)	5 oz.	150 cc
Sodium sulphite	½ oz.	15 g
Acetic acid (28 per cent)	1½ oz.	45 cc
Potassium alum	½ oz.	15 g
Add solution 2 to 1 after cooling, and add		
water to make	32 oz.	1000 cc

Dissolve chemicals thoroughly in the order given and stir rapidly when adding solution 2 to solution 1. When this bath froths, turns cloudy, or takes longer than 10 minutes to fix out completely, it is exhausted and should be discarded.

The addition of boric acid to a fixing bath gives it a longer useful life, and less tendency to sludge. A bath containing acetic acid, potassium alum, sodium sulphite, and hypo gives satisfactory hardening only through a *pH*

range of about 4.2 (that of the fresh bath) to 4.28. It will not harden if the acidity is much above or below these figures. With the addition of boric acid it will harden with a pH value up to 6.

ACID-HARDENING FIXING BATH (Eastman F-5)

Water (about 125° F.) (52° C.)	80 oz.	2500 cc
Hypo	2 lb.	960 g
Sodium sulphite	2 oz.	60 g
Acetic acid (28 per cent)	6 fluid oz.	190 cc
Boric acid (crystals)	1 oz.	30 g
Potassium alum	2 oz.	60 g
Cold water to make	128 oz.	4000 cc

Crystalline boric acid should be used as specified. Powdered boric acid dissolves only with great difficulty and its use should be avoided.

If films are fixed in a tank, they should be left in the developing hangers. They should be fixed properly in 10 minutes if a freshly prepared fixing bath has been used. Leaving them in the solution a few minutes longer than the time specified will not do any harm, but prolonged immersion, especially in warm weather, may tend to bleach the image.

When the total fixing time (twice the time to clear) exceeds 20 minutes, the F-5 bath should be discarded. This will occur usually after eighty to one hundred 8 by 10-inch films (or their equivalent in other sizes) have been fixed per gallon (4 liters). This bath gives good hardening, and should not sludge throughout its useful life.

STOCK HARDENER SOLUTION (Eastman F-5a) (For use with Formula F-5)

Water (about 125° F.) (52° C.)	80 oz.	2500 cc
Sodium sulphite	10 oz.	300 g
Acetic acid (28 per cent)	30 fluid oz.	940 cc
Boric acid (crystals)	5 oz.	150 g
Potassium alum	10 oz.	300 g
Cold water to make	128 oz.	4000 cc

Crystalline boric acid should be used as specified. Powdered boric acid dissolves only with great difficulty and its use should be avoided.

A fixing bath is made by adding 1 part of cool stock hardener solution to 4 parts of cool 30 per cent hypo solution [2½ lb. hypo per gallon of water (1200 grams per 4 liters)] while stirring the hypo rapidly.

Fixing baths containing chrome alum, when fresh, have a greater hardening power than baths containing potassium alum, but they lose this ability rapidly whether in use or not. The tendency to scum is less than with potassium alum, but excessive when once started, and if the scum has dried on the film, it is much more difficult to remove. If too much chrome alum is used, it will stain the film green. Boric acid does not increase the hardening life nor the sludging life of a chrome alum bath as it does that of a potassium alum bath. The fresh bath has a pH value of about 3 and it hardens well only up to a pH of 3.8. The excessive hardening secured by chrome alum makes it particularly desirable under tropical conditions, but the bath should be discarded every few days whether used or not, as it rapidly deteriorates.

CHROME ALUM FIXING BATH (Eastman F-16)
(For general use with films and plates)

Solution A

Hypo	2 lb.	960	g
Sodium sulphite	2 oz.	60	g
Water to make	96 oz.	3000	cc

Solution B

Water (not above 125° F.) (52° C.)	32 oz.	1000	cc
Potassium chrome alum	2 oz.	60	g
Sulphuric acid, C. P.	$\frac{1}{4}$ fluid oz.	8	cc

Pour solution B into solution A slowly while stirring A rapidly. Always rinse the films thoroughly before fixing. This bath is recommended for use in hot weather. With an old bath there is a tendency for scum to form on the surface of the film. Any such scum should be removed by swabbing with cotton before drying.

RAPID AMMONIA FIXING BATH.—Ammonium Chloride, NH_4Cl (sal ammoniac), is sometimes added to a fixing bath to speed up its action. For each concentration of hypo there is an optimum concentration of ammonium chloride, which decreases as the concentration of hypo becomes greater. If a 20 per cent solution of hypo is used, the addition of from $2\frac{1}{2}$ per cent to 5 per cent of ammonium chloride increases the rapidity of fixing. With a 40 per cent solution of hypo, however, it has no effect. While of advantage in cases of emergency, the use of ammonium chloride in a fixing bath is not recommended for general use, as complex hyposulphites of silver and ammonia are formed which entail the risk of discoloration of the image. The addition of 10 per cent of ammonia water to a 20 per cent solution of hypo acts as quickly as the ammonium chloride.

RESIDUES.—To precipitate metallic silver from old hypo baths, from 420 to 560 grains per gallon (6 to 8 g per 1000 cc) of sodium hydrosulphite, $\text{Na}_2\text{S}_2\text{O}_4$, should be added, with about half that quantity of caustic soda, and the bath heated to boiling point to decompose the excess of hydrosulphite. This treatment regenerates the hypo and the fixing bath can be used again. There is, however, no particular saving, due to the low cost of hypo. More hypo and hardener have to be added and the silver value recovered is low. An average exhausted bath carries about 0.1 to 1 ounce troy of silver per gallon (0.7 to 7.2 g per 1000 cc). Only $33\frac{1}{3}$ to 50 per cent is recovered and it is not profitable unless about 5 gallons of exhausted fixing solution per week is available.

When the hydrosulphite is in slight excess, all the silver is precipitated but it will not settle for 2 or 3 hours. Safranine dyes increase the rate, but do not help if settling is given a day to work.

The above method is recommended for an alkaline fixing bath, but with anhydrous sodium sulphite, a rapid precipitation can be effected at a temperature of 122° to 140° F. (50° to 60° C.) if the chemicals are in slight excess. Overnight precipitation is complete at room temperature.

Rongalite, a hydrosulphite derivative, can also be used, better in an acid

solution than in one that is alkaline. Heating is necessary for complete and speedy precipitation. All of these methods are rather expensive as compared with the zinc or sodium sulphide methods.

The addition of a saturated solution of potassium sulphide, also known as liver of sulphur, will precipitate the silver from old fixing baths. This should be done out of doors as sulphuretted hydrogen is evolved. The mixture should be well stirred and the silver sulphide allowed to settle down; then some of the clear supernatant liquid should be collected in a graduate and tested with a drop or two of liver of sulphur solution. A deep brown color or blackish precipitate shows the presence of silver in solution, and then more sulphur compound should be added.

If the waste solutions are made alkaline before precipitation, the odor is neutralized to some extent. One ounce of sodium hydroxide per gallon (7.5 g per 1000 cc) is needed for an average acid fixing bath, which will redissolve the aluminum sulphite precipitate which is formed. With a chrome alum fixing bath, chromium hydroxide is formed, but with bisulphite hypo or a plain hypo bath there is no precipitate. While the disappearance of the precipitate indicates alkilinity, a test with red litmus paper is better. Then 60 grains per gallon (1 g per 1000 cc) of sodium hydroxide will dissolve the aluminum compounds and make the bath alkaline and prevent sulphide odors.

About 290 grains per ounce (5 g per 1000 cc) of fused sodium sulphide will precipitate 1 gallon of old fixing bath. Hot water speeds up the solution but this must never be done anywhere near any sensitive materials. Sulphide precipitates are best left to settle over night.

The sludge can be filtered through a layer of sawdust 2 or 3 inches in depth in an old bucket with a perforated bottom. While the silver can be tested for in a small quantity of clear solution, excess of sulphide will show if a piece of absorbent paper is moistened with lead acetate and dipped into the bath, when a darkening of the paper will show an excess of sulphide. The clear supernatant liquid can be tested in a graduate with a drop of sulphide solution. A tinge of color or a slight precipitation will indicate incomplete precipitation of the silver.

Zinc is a more cleanly precipitant. This can be used either in scrap or mossy form. The liquid should be well stirred and allowed to settle and this operation should be repeated three times at intervals of 24 hours. The clear liquid may be tested as suggested above. About 3 days is sufficient, as a rule, to throw down the whole of the silver.

One of the best methods of regaining silver from old fixing baths is to procure a sheet of brass, not too thin, and place it in the barrel or jar at an angle, so that both sides are presented to the liquid. After about 48 hours the whole of the silver will be precipitated in the metallic form on the brass and can usually be removed by bending a corner sharply two or three times, when the silver will spring off. The brass can then be put back into the vessel

and allowed to remain another 24 or 48 hours, when practically the last traces of silver will be extracted. This thin coat may be difficult to remove and may be left on the brass until the next batch of residues is to be treated.

Electrolytic treatment with current will precipitate silver, but an electrolytic coupler as leased commercially for use will make its own current. Some of these couplers have zinc and copper plates and a brass plate not in electrical contact. This is started in an old hypo bath and then in the working bath. Silver accumulates on the unit. They work more quickly from an alkaline bath. From 75 to 90 per cent of the silver is recovered in a week. Another type has a zinc and a copper electrode and is recommended for exhausted baths. About 85 per cent of the silver comes out in 2 weeks. While the life of a working bath might be lengthened by the continuous removal of the silver, this is of doubtful advantage, but for the recovery of silver from moderate quantities of old baths, this process is excellent.

TWO-BATH FIXING. — The best way to insure complete fixation is by the use of two baths, which may be identical in composition. After the negative has been fixed in the first bath, it is transferred for a period of about 5 minutes to the second. Developer and oxidation products that begin to accumulate in the first bath as soon as it is put to work, retard the process of fixation. These products are left behind in the first bath and the negative is treated with uncontaminated hypo in the second. When the first bath shows signs of exhaustion by fixing slowly, it is replaced by the second, and fresh solution mixed for the second bath. The usual practice is to discard the first bath when work for the day is finished and to save the second bath to use as a first bath at the next working session.

WASHING. — The rate of washing depends largely upon the rate of diffusion of hypo from the film into the water, and the rate at which this hypo-laden water is removed from the vicinity of the film. The rate of washing is not influenced by previous hardening of the emulsion unless the gelatin has been allowed to dry after hardening. With negatives, it is not influenced by the temperature of the wash water. Salts diffuse more quickly in warm water than in cold, but the warmer the water, the more the gelatin swells, and this swelling hinders diffusion as much as the increased temperature accelerates it, so that the rate of washing is about the same at all ordinary temperatures. The solubility of the compounds that are to be washed out determines only the proportion of them that will be removed, and has no effect upon the diffusion rate.

An average negative washed directly under a stream of water of sufficient volume will give up half its hypo in 15 seconds. In a tray or tank it will do so in about 30 seconds. Under the stream of water, by the law of fractional reduction the negative will yield half the remaining hypo in another interval of time equal to the first. And so on until the amount remaining is soon infinitesimal. This process will not continue in the tray or tank unless all

the water is removed and fresh supplied at the end of each interval. The rate of washing is dependent upon the degree of agitation and the rate at which the contaminated water is withdrawn and replaced with fresh. This rate depends upon the ratio between the size of the stream supplying the water and the size of the tank or tray in which the washing is done. The time taken to completely change the water in any washing device can be determined by putting an ounce of 5 per cent potassium permanganate, or of red ink, into the tray or tank while the water is running, and noting the time it takes for the water to become completely colorless.

The minimum time that is necessary for washing under most efficient conditions, such as under a large volume of swiftly running water, varies with different materials.

MINIMUM WASHING TIME

Lantern slides	3 minutes
Plates	5 minutes
Films	7 minutes

If the time it takes the water to completely change in a washing device is added to the time given above for any material, it will show the minimum time for thorough washing of that material in that washing device. For instance, if it takes the water 10 minutes to clear, the time for a film would be 17 minutes.

Fine-grained negatives require longer washing than coarse-grained ones and can never be considered thoroughly washed unless they have had an hour's washing under most efficient conditions. Failing this, the image is quite likely to fade in the course of time.

If, during the process of washing, a negative is touched with a finger contaminated by hypo, or if a negative fresh from the hypo is placed with other negatives which are partly washed, the hypo thus introduced into the bath will be diffused into all the negatives, and washing must start anew from that time.

When water has to be economized, negatives can be washed in successive changes of small volumes of water, leaving them in a tray of water from 2 to 5 minutes and then transferring them to another tray with fresh water, and repeating the process until they are washed.

HYPOTESTS. — Whether using the tray method of changing the water, or some standard washing device, tests may be run to find out when all the hypo is eliminated. When such a test has been made, it can be assumed that like results will be secured under similar conditions for the future.

HYPO TEST SOLUTION (Eastman HT-1a)

Distilled water	6 oz.	180 cc
Potassium permanganate	4 gr.	0.3 g
Sodium hydroxide (caustic soda)	8 gr.	0.6 g
Water (distilled) to make	8 oz.	250 cc

Take 8 ounces (250 cc) of pure water in a clear glass and add $\frac{1}{4}$ dram (1 cc) of the Hypo Test Solution. Then take one 8 by 10-inch film or plate, or its equivalent in other sizes (two 5 by 7-inch or four 4 by 5-inch, etc.), from the wash water and allow the water to drip for 30 seconds from its surface into the glass containing the Hypo Test Solution.

If a small percentage of hypo is present, the violet color will change to orange in *about 30 seconds*, and with larger concentrations of hypo the orange color will change to yellow. In either case the washing should be continued. When further tests produce no change in the violet color, this indicates that the hypo content has been reduced to a safe margin, thereby insuring satisfactory permanency.

Oxidizable organic matter if present in the water, reacts with the permanganate solution and changes its color in the same manner as hypo. The water should, therefore, be tested as follows:

Prepare two samples of permanganate test solution, using distilled water. Then add a volume of the tap water to one test sample equal to that of the wash water drained from the plate into the other sample. If the sample to which tap water has been added remains a violet color, this indicates the absence of organic matter and it will be unnecessary to make the test in duplicate. If the color is changed slightly by the tap water, however, the presence of hypo in the plate will be shown by the relative color change of the two samples. For example, if the tap water sample turned pink and the wash water sample became yellow, it would indicate the presence of hypo, while if both turned the same shade this would indicate the absence of hypo.

Note that this test shows only the thoroughness of the elimination of the hypo, and is in no way a guarantee of the permanence of the negative, which depends quite as much upon the efficiency and thoroughness of fixation as it does upon the elimination of hypo.

A more conclusive test suggested by Crabtree and Ross is made by the following:

Mercuric chloride	365 gr.	25 g
Potassium bromide	365 gr.	25 g
Water to make	32 oz.	1000 cc

A piece of the film about 1 inch square is immersed in about $\frac{1}{2}$ ounce of the solution. If hypo is present, a milky precipitate will occur in 10 or 15 minutes. The image will be bleached white, but no precipitation will occur if there is no hypo in it.

HYPHO ELIMINATORS.— Various substances, usually oxidizers, have been recommended to destroy the hypo in the emulsion, to save the time of eliminating it by washing. Most of these substances attack the silver of the image, and all of them react with the hypo to form products which are probably as dangerous to the image as hypo itself is. To use them with all the precautions

necessary to safeguard the image, is a longer and far more complicated process than washing. If permanence of the image is considered, there is no substitute for washing.

DEFERRED WASHING.—When sufficient water is not available for washing immediately after fixation, or when the available water is so warm as to endanger the emulsion, three successive soakings for 5 minutes each will remove most of the hypo, and the negative can then be dried, and washed at a later time. While a negative washes more quickly if it has been hardened so that the swelling of the gelatin is kept to a minimum, this is true only provided it has not been dried between fixing and washing; but once the hardened gelatin has been dried, it is much more difficult to wash and it is even doubtful if it can ever be softened enough again to permit the most thorough washing.

DRYING.—The purpose of drying is not to completely desiccate the gelatin, but to reduce its moisture content to about that of the air in which it is to be kept. It is considered dry when it has no more than about 15 per cent of moisture. With less than this, films are very brittle and even plates are liable to injury. About three-quarters of the water in a wet negative will run off if it is suspended vertically, but the rest has to be evaporated.

Surface moisture should first be wiped off with absorbent cotton, a piece of chamois, or a viscose sponge, which has been soaked in water and wrung out. Rubber squeegees are convenient for removing the surface moisture from strip film. Whatever the mechanical means used, great care should be taken that the implement is free from dust, which is sure to cause serious scratches on the emulsion as it is very tender when wet. Implements should be frequently washed in boiling water, and kept in covered glass jars when not in use. Drops of water left on negatives when set to dry are sure to show drying marks due to the different drying time between them and the surrounding surface of the emulsion. When cut film is washed and dried in hangers which grip the edge of the film, water is trapped under the jaws of the hanger and should be blown out before the films are hung up to dry, as it will otherwise slowly diffuse into the film and cause uneven drying.

The time required for drying depends upon the amount of water in the gelatin and the humidity of the air, its temperature, and how much it circulates. The amount of water taken up by the gelatin depends upon the thickness of the gelatin and the degree to which it has been swollen by previous processes. If the gelatin has been hardened, it contains little water and dries rapidly. The rate of drying varies nearly inversely to the humidity of the air. Warming the air decreases its humidity, but this cannot be carried beyond 90° F. without danger of melting the gelatin unless it has been hardened. Somewhat higher temperatures may be used with negatives hardened by alum, and by the use of chrome alum they may be made to stand temperatures between 120° and 140° F. As the air in the vicinity of the

negative becomes saturated with the moisture that it has taken up, drying stops until the air in contact with the emulsion surface is renewed. A small current of rapidly moving air playing directly on the surface is more efficient than a large volume of air moving slowly. Any sudden change of temperature, of humidity, or of the movement of the air during drying is likely to show a difference in the negative between the parts dried under different conditions. Hot, dry air is likely to dry the surface of the gelatin first, trapping moisture in the underlying portions. When this moisture is redistributed in the gelatin, it becomes so moist that the negative is liable to injury by the conditions under which it is stored.

Drying in a very hot and humid atmosphere increases both the density and contrast of a negative, under extreme conditions by so much as 25 per cent. Graininess is greatly increased by slow drying of swollen film at high temperatures.

DRYING WITH ALCOHOL. — If a wet negative on glass is placed for 2 or 3 minutes in alcohol 90 parts, water 10 parts, the alcohol will have almost entirely displaced the water in the gelatin, and it will then dry very rapidly in a current of air, which may be warmer than if the gelatin were wholly charged with water, but safest results are obtained at about 70° F. Too strong a concentration of alcohol produces opalescence of the image, which Lüppo-Cramer attributes to partial dehydration of the gelatin. The alcohol becomes enough diluted by the water from three or four negatives to render it useless, but it can be regenerated by shaking it with plaster of Paris or the carbonate of soda or potash which are not soluble in alcohol, but take up the water.

With the alcohol treatment, the presence of lime in the water is likely to give a whitish deposit on the negative which is difficult to remove.

DRYING BY DEHYDRATION. — A wet negative placed for 4 or 5 minutes in a saturated solution of potassium carbonate is almost completely dehydrated. Surface solution is blotted off with blotting paper, and after wiping the negative with a soft cloth, it is ready for printing. It must be subsequently washed to remove traces of the potassium carbonate. When using this process, time can still further be saved by shortening the time of both fixing and washing, and afterwards performing both these operations thoroughly, at leisure.

CHAPTER V

DEFECTS IN NEGATIVES

GENERAL FOG is due to any one of a great number of causes among which the following are most common: (1) Accidental exposure to light. (2) An unsafe safelight. (3) Overlong storage, or bad storage conditions, including long stays in magazines, camera, or holders. (4) Overexposure, or reflections in the lens when working against the light. (5) Overdevelopment, especially in a developer containing too much alkali. (6) Aerial fog due to too frequent removal of the negative from the developer. (7) Too warm a development temperature. The only positive cure for general fog is to reduce the negative in weak Farmer's reducer which is often wholly or at least partially successful. In case of general fog, if the space under the rabbets that hold the negative in the film holder is unfogged, it is conclusive evidence that the fogging occurred while the emulsion was in the camera, whereas if the fogging extends clear to the edge of the negative, it proves that the fog occurred outside of the camera.

DICHOIC FOG.—This fog is easily identified because it appears green by reflected light and red by transmitted. It is most pronounced in the shadow areas of a negative and is due to the deposit of silver in a colloidal state which may be caused by a trace of hypo in the developer, or by action of traces of developer in the fixing bath when the emulsion is partially fixed, as may occur when one film sticks to another in the hypo bath. It may be reduced by the following:

Potassium permanganate	5 gr.	$\frac{1}{2}$ g
Water	10 oz.	450 cc

After the fog is reduced by treatment in this bath, the negative is rinsed and cleared of stain by a 5 to 10 per cent bath of potassium metabisulphite, followed by washing.

Another formula for reducing dichroic fog is:

Sodium sulphite	1 oz.	50 g
Potassium cyanide	100 gr.	10 g
Distilled water	20 oz.	1000 cc

Streaks of fog running across a negative are usually caused by leaks in holders, imperfect fitting of holders to camera, and in the case of rollfilm, by changing film in direct sunlight.

MARGINAL FOG is usually an incipient case of what would later be general fog caused by too long or improper storage.

THE IMAGE DOES NOT DEVELOP. — Either the negative was not exposed, on account of faulty operation of the shutter, or an error in manipulation; or some important ingredient has been left out of the developer. With backed films or plates, if the emulsion has been reversed in the holder so that the negative was exposed through the back, the image may be so slow in coming up as to lead one to believe that it will not appear.

BLACK SPOTS on a negative are usually caused by undissolved chemicals in the developer and can be prevented by filtering the solution.

PINHOLES are caused by dust in the camera which settles on the sensitive material. The remedy is to occasionally wipe out the interior of the camera, including the bellows, with a damp cloth.

ROUND CLEAR SPOTS on a negative are caused by air bubbles on the surface of the film which were not broken by sufficient agitation when the film was put into the developer.

HOLES in the emulsion are caused by damage from fingernails and by bacteria attacking the emulsion while it is drying.

BLACK LINES twisting all over the negative are caused by a hole in the bellows, in the curtain of a focal plane shutter, or by a small opening left by imperfect closing of the leaves of a diaphragm shutter. Any of these small openings will act as a pinhole through which the image moves in all directions as the camera is moved.

SPREADING THE HIGHLIGHTS into the shadows is caused by using an emulsion not protected against halation when photographing contrasty subjects.

SCRATCHES are caused by friction usually occasioned by dust on the rollers of rollfilm cameras or in the holders of cut film, filmpack, or plate cameras.

MOTTLING is caused by too short development of overexposed negatives so that the developer does not fully permeate the emulsion, or by lack of agitation during development.

TREE-LIKE MARKS are caused by electrical discharges upon the film, occasioned by friction when changing the film in very dry weather, especially in the winter.

DUPLICATE IMAGES are usually caused by inadvertently making two exposures upon the same negative. A somewhat mystifying second image is sometimes caused by a pinhole which may be a hole in the bellows of the camera or caused by a screw dropping out of the lens mount. The camera may be left in such a position that an image of a light object in front of it is focused by this pinhole on the sensitive emulsion.

POSITIVES instead of negatives are sometimes caused by excessive overexposure which gives a whole or partial reversal of the image. This may be caused by a sticking shutter or by faulty manipulation of the shutter leaving it open when it is supposed to be closed.

DARK CIRCLE IN CENTER. — This is caused by the shutter working when the bellows is closed, as in the accidental tripping of the shutter when the camera is closed.

LATERAL REVERSAL OF THE IMAGE is caused by loading the film into the camera with the emulsion to the rear.

BLURRED IMAGES are caused by: (1) Movement of the object during exposure to a degree greater than the shutter speed would stop. This error can be easily detected because all stationary objects in the picture will be sharp. (2) Movement of the camera during exposure. People vary greatly as to the length of exposure that can be hand-held without showing motion. For critical sharpness of an image which has to be greatly enlarged, 1/100 second is as long an exposure as can be safely held by the average person. Even when a camera is on a tripod, movement may be caused by a jar or by vibration from the wind. (3) The image was not correctly focused. This may be due to faulty eyesight when focusing visually, or to a lack of register between the groundglass and the sensitive material. Scale-focusing cameras are little likely to derangement but the scale should occasionally be checked by making exposures at measured distances.

HARD AND DENSE NEGATIVES may be caused by overdevelopment or wrongly compounded developer.

EXCESSIVELY THIN NEGATIVES are usually caused by underexposure or too short development. The latter is often caused by failing to give increased development time when the developer is cold, or by using an exhausted developer.

RETICULATION may be caused by too warm developer or great changes between the temperature of the developer, the fixing bath, and the wash water.

SMALL CRYSTALS are usually dried hypo and indicate imperfect washing. Soak the negative and re-wash it thoroughly. If the wash water contains an excessive amount of lime, a deposit may be made upon the surface of the negative unless it is swabbed with wet cotton before it is put to dry.

THE EMULSION BECOMES DETACHED FROM THE BASE. — This is caused by too great difference in temperature of the various baths used in developing, fixing, and washing.

BROWN STAINS UPON A NEGATIVE are usually caused by an overworked fixing bath which has lost its acidity. The stains can generally be removed by the use of a bath containing a few drops of potassium metabisulphite.

DRYING DROPS. — Small round dots of greater density than the surrounding area of the film indicate drops of water on the film when it was drying. If they are still damp when discovered, the remedy is to resoak the film and repeat the drying. Before a film is hung up to dry, all drops of water should be removed from its surface by the use of a wet chamois or a viscose sponge or a piece of damp cotton. The chamois or viscose sponge should be kept in a jar with a tight-fitting cover so that no dust will settle on it when not in

use, as dust will scratch the film when wiping off the water drops. Water drops when not too intense sometimes do not show on the print. They can often be removed, at least partially, by bleaching the film in the chromium intensifier bleach to which has been added a little extra hydrochloric acid, then redeveloping and washing again.

SPECKS OF DUST IMBEDDED IN THE FILM may be caused by mineral deposits from the wash water. Use a filter on the faucet. They cannot be removed after they have dried into the emulsion, but they are easily removed by swabbing with cotton before the film is hung up to dry, and this should be a standard practice. Dust also gets imbedded in an emulsion by allowing it to dry in a dusty atmosphere, especially if there is a current of air.

NEWTON RINGS are irregular spots of color which appear upon the paper during enlarging. They are occasioned by irregular pressure upon the film caused by its not lying flat, usually when the film is in contact with a condensing lens in a vertical enlarger, or when held between two glass plates. This trouble occurs very frequently when using film that is only surface dry, or film that has been allowed to dry in a concave shape. It is completely remedied by allowing the film to become thoroughly dry under a slight weight to make it lie flat. The trouble can also be eliminated by using a cut-out platen between the negative and the source of pressure.

SCRATCHES may be caused by local mechanical injury, or they may consist of fine markings caused by abrasion by careless handling. If the scratches are on the gelatin backing of the film they can be gotten rid of by removing the backing (see page 347). Most scratches can be minimized if not entirely obliterated by enclosing the film in glycerin between two cover glasses and printing by projection through this sandwich. Pour a small pool of glycerin on the center of the glass and lay the side of the film that has the scratches in the glycerin. Cover with another glass and press down until glycerin exudes from all sides of the negative, pressing out as much as possible.

STAINS ON NEGATIVES. — For removal of stains, see page 338.

CHAPTER VI

DUPLICATING NEGATIVES

For a variety of reasons, duplicate negatives are often wanted. They are a safeguard against the total loss of a valuable negative. Retouching and alterations can be made upon them that one would hardly dare risk doing upon the original. They can be made either the same size as the original, or larger or smaller at will, to meet special requirements. Negatives are made in duplicate for large printing orders so that several prints can be made at the same time. Enlarged negatives permit handwork and retouching that would be impossible in the smaller size, and they are often used as a step-up for excessive enlargements. A great many of the control processes are printed by contact and this requires a negative as large as the finished print.

DIAPOSITIVES.— The first step in making an enlarged negative is to make a diapositive, which may be done either by contact printing or by projection. A *diapositive* is a positive through which light is to be transmitted, as distinguished from a print, which is a positive made to be seen by reflected light. The projected positive may be the same size as the original, or larger or smaller, as desired. The diapositive may be made upon any plate or film, but for convenience in handling, the slower commercial emulsions are generally used. These also have the advantage of giving a very fine grain. The diapositive should have the same qualities as a negative. That is, if it is to be used for further reproduction it should be printed considerably darker than if it is to be used for viewing as a transparency. By developing a diapositive to a suitable gamma, the contrast of the original may be increased or reduced if this is desirable. When the diapositive is to be used for making a new negative it is good practice to make it as near like the original as possible and make the changes in contrast upon the final negative. This eliminates one of the variables in the process and all the alterations are made at one time upon the final negative. When the diapositive is used only as a step towards a new negative, all the retouching upon it should consist in adding pigment to darken any areas that need it. Areas can be lightened by a similar application of pigment to the desired parts of the negatives. This method does away entirely with any necessity for etching, which is a highly specialized technique, and much more difficult than adding pigment.

THE NEW NEGATIVE.— The new negative may be made in the same way as the diapositive, by contact printing or by projection, and by developing to a suitable gamma may be made to the same contrast as the original

or may be altered to any degree to suit special requirements. If the exact quality is not obtained in the development, the negative may be intensified or reduced.

NEGATIVES BY REVERSAL. — Duplicate negatives may be made by the reversal process which eliminates the positive entirely and is often used when no retouching is necessary upon the positive. Negatives by the reversal process are admitted to have the finest grain that can be secured by any process, hence they are quite popular for the step-up method of making huge enlargements. Part of the enlargement is secured upon the new negative, making it as large as the projection apparatus will accommodate, and the final result secured by further enlargement from it.

While negatives can be made by reversal upon almost any kind of film, the process is rather tricky and it is better to use the special reversing films made by some manufacturers and to follow their directions. For the Agfa Superpan Reversal film the directions are as follows:

1. First developer.

Solution A

Warm water (about 125° F.)	24 oz.	750 cc
Metol	29 gr.	2 g
Hydroquinone	219 gr.	15 g
Sodium sulphite	292 gr.	20 g
Sodium bisulphite	73 gr.	5 g
Hypo	73 gr.	5 g
Formaldehyde	75 minims	5 cc
Cold water to make	28 oz.	900 cc

Solution B

Cold water	4 oz.	100 cc
Sodium hydroxide (caustic soda)	365 gr.	25 g

2. Wash for 5 minutes in running water.

3. Reversing bath (bleach).

Water	32 oz.	1000 cc
Potassium bichromate	73 gr.	5 g
Sulphuric acid (concentrated)	75 minims	5 cc

The normal bleaching time is from 3 to 6 minutes. Keep the film in the bleaching bath until the negative image is completely dissolved.

4. Wash for 5 minutes in running water.

5. Clearing bath.

Water	32 oz.	1000 cc
Sodium sulphite	1½ oz.	50 g

Clear for 5 minutes.

6. Wash for 5 minutes in running water.

7. Expose to Mazda light or diffused daylight.

8. Second developer.

Warm water (about 125° F.)	32 oz.	1000 cc
Metol	73 gr.	5 g
Hydroquinone	88 gr.	6 g
Sodium sulphite	1½ oz.	40 g
Potassium carbonate	1½ oz.	40 g
Potassium bromide	88 gr.	6 g

Develop for 5 minutes at 65° F.

9. Give the film a short rinse in running water.

10. Fixing bath.

The same fixing bath may be used as for other films, or it may be prepared as follows:

Water	32 oz.	1000 cc
Hypo	10 oz.	300 g
Potassium metabisulphite	1½ oz.	50 g

Sodium bisulphite may be used instead of potassium metabisulphite, weight for weight. It is cheaper and just as effective. Fix the film for 2 minutes.

11. Wash for 30 minutes in running water.

12. Glycerin bath.

Water	32 oz.	1000 cc
Glycerin, C.P.	320 minims	20 cc

Leave the film in this glycerin bath for 5 minutes.

13. Remove excess moisture with a viscose sponge or a piece of chamois and dry the film in a current of warm air.

DIRECT COPY NEGATIVES.—The Agfa Direct Copy film provides an interesting way of making duplicate negatives by direct printing and development which results in a positive from a positive or a negative from a negative. While enlargements may be made upon this emulsion, it is so slow that it is more convenient for contact printing than for enlarging.

PAPER NEGATIVES.—When an enlarged negative is to be made, there are sometimes advantages in making it upon paper rather than upon a plate or film. The expense is much less, storage space is much less than for glass, all danger of breakage is eliminated, and retouching upon it is much easier. It is generally used for broad effects where it is not necessary or is undesirable to carry all the detail of the original, although with proper care, a paper negative may show very little loss of detail. While the paper negative is usually printed upon chloride, bromide, or chlorobromide paper, it is also admirably suited for carbon, Fresson, or gum printing, and it affords an easy and inexpensive method of getting negatives in any size for these processes.

There are several methods of making a paper negative. It may be made from a diapositive which is usually made for economy in a much smaller size than the final negative is to be. From the diapositive a print is made either

by contact or by projection upon a smooth, fine-grain, single-weight paper, resulting in a negative upon paper. Retouching may be done upon either the positive or the negative as in the case of making regular negatives.

Another method is to make a diapositive upon paper the size of the desired negative and print this by contact upon another sheet of paper. The base stock of the paper has irregularities which do not appear in the emulsions coated upon glass or film, and by any direct process these irregularities appear in the negative and are shown in the final print. For broad pictorial effects this is often considered an advantage, but where it is desired to show finer detail, the grain of the paper can be eliminated by suitable procedure. The diapositive is made upon film and this is projected through the back of the paper to make the final negative. The diapositive must be reversed in the enlarger to bring the subject the right way about on the resulting negative. In this way all irregularities in the paper are compensated for in the emulsion and while they show upon the surface of the negative when viewed by reflected light, by transmitted light they entirely disappear.

Diapositives and negatives upon paper must be made with the same qualities that appear in negatives upon regular emulsions. They should be printed and developed so dark that the surface appears like that of a negative and the detail can be seen only by transmitted light.

Extensive retouching and alteration can easily be made upon either a diapositive or the negative on paper. This is done by the use of pencils, crayons, or water color wash. Graphite in the form of stove polish, applied with a broad stump, is a favorite medium.

Agfa's New Coccine is excellent for smooth washes upon paper negatives. Farmer's reducer may be used for over-all or for local reduction. Interesting work can be done with colored pencils. Very delicate effects are produced by using a blue pencil, and stronger effects by using brown or red pencils. Bluing as used domestically in the laundry can be applied with an artist's stump. Modifications can be made upon either the face or the back of the paper. Clouds are easily worked into a plain sky by the use of a stump on the back of the paper.

Paul L. Anderson gives the following directions for making enlarged paper negatives by direct reversal.

DEVELOPER

Water	25 oz.	750 cc
Sodium sulphite	716 gr.	48.8 g
Hydroquinone	358 gr.	24.4 g
Boric acid (crystals)	82 gr.	5.6 g
Potassium bromide	38 gr.	2.6 g
Sodium hydroxide (caustic soda)	358 gr.	24.4 g
Water to make	32 oz.	1000 cc

BLEACHER

Water	32 oz.	1000 cc
Potassium bichromate	138 gr.	9.6 g
Sulphuric acid (concentrated)	3 drams	12 cc

CLEARING BATH

Water	32 oz.	1000 cc
Sodium sulphite	1320 gr.	90 g

Any thin bromide paper may be used, but Eastman Translite or Defender Adlux films which are coated with a chlorobromide emulsion upon both sides are advantageous on account of their mat surface, when pencil work is to be done upon the negative. As this is a reversal process, negatives thin enough for convenient printing are obtained only by exposures several times as long as would be required for positive prints upon the same material. Development should ordinarily be to finality, or it may be shortened to reduce contrast. The process of development may be followed by inspection under a Wratten OA safelight.

Rinse the bromide paper in four or five changes of water after development, and then immerse in the bleacher for 30 seconds or so longer than it takes the image to disappear. With the double-coated films the image may not entirely disappear, but it is easy to see when it ceases to bleach any more. Rinse again in four or five changes of water, immerse in the clearing bath, and turn on the white light, to which both the front and back of the films should be exposed. Two or 3 minutes exposure at 2 feet from a 100-watt lamp may be used, but avoid direct sunlight. From this point on, all work is conducted in full light. Clearing should be thorough, as any bichromate left in the film will cause irregularity in the second development. This takes about 1 minute for papers, and up to 5 minutes for the double-coated films.

After another thorough rinsing, the negative is redeveloped to finality in the original developer. Fixing is unnecessary, and the process is completed by 5 minutes washing in running water.

Negatives may be reduced or intensified by any of the standard processes, except chromium which is likely to produce stain. Before attempting either intensification or reduction, the negative should be hardened in the following bath:

HARDENING BATH

Water	32 oz.	1000 cc
Formalin	2½ drams	10 cc
Sodium carbonate	70 gr.	5 g

CHAPTER VII

INTENSIFICATION

Errors in exposure time, and in developing time, can often be largely compensated for by appropriate intensification or reduction of the negative. The various processes of intensification usually change the silver to a silver salt or a mixed compound which is made more opaque by redevelopment.

HARDENING OF NEGATIVES FOR AFTER-TREATMENT.—Most of the processes of chemical reduction, intensification, and stain removal have a softening action on the gelatin. Precautions should be taken to harden the negative previous to such treatment. The following hardening bath is recommended especially for negatives which are to receive after-treatment:

FORMALIN HARDENER (Eastman SH-1)

Formalin (40 per cent formaldehyde solution)	2½ drams	10 cc
Sodium carbonate (desiccated)	70 gr.	5 g
Water to make	32 oz.	1000 cc

After hardening for 3 minutes, negatives should be rinsed and immediately immersed for 5 minutes in a fresh acid fixing bath and washed thoroughly before being given any further chemical treatment.

The increase in density, known as intensification, is accomplished by depositing additional silver or some metallic compound on to the image, or by the formation of an image of non-actinic color. It is used upon negatives that have received too short a development, either inadvertently, or from fear that longer development would produce fog. It is also used when greater contrast is wanted than could be produced by development.

SILVER INTENSIFIER.—When intensifying with silver, the amount deposited is practically proportionate to the amount in the image, so that the result is much the same as if the negative had been developed to a higher gamma. The intensified image is of silver and is as permanent as the original. Of the many different formulas for this process, one of the best is that developed by Crabtree and Muehler.

This is the only known intensifier which gives an image of neutral color. The progress of intensification may be followed visually and arrested at any stage.

SILVER INTENSIFIER (Eastman In-5)

<i>Stock Solution No. 1</i>		
(Store in a brown bottle)		
Silver nitrate (crystals)	2 oz.	60 g
Water, distilled, to make	32 oz.	1000 cc
<i>Stock Solution No. 2</i>		
Sodium sulphite	2 oz.	60 g
Water to make	32 oz.	1000 cc
<i>Stock Solution No. 3</i>		
Sodium thiosulphate (Hypo)	3½ oz.	105 g
Water to make	32 oz.	1000 cc
<i>Stock Solution No. 4</i>		
Sodium sulphite	½ oz.	15 g
Elon	350 gr.	24 g
Water to make	96 oz.	3000 cc

The intensifier solution is prepared as follows:

Slowly add 1 part of solution No. 2 to 1 part of solution No. 1, shaking or stirring to obtain thorough mixing. The white precipitate which appears is then dissolved by the addition of 1 part of solution No. 3. Allow the resulting solution to stand a few minutes until clear. Add, with stirring, 3 parts of solution No. 4. The intensifier is then ready for use and the film should be treated immediately.

The degree of intensification obtained depends upon the time of treatment which should not exceed 25 minutes. After intensification the film should be immersed and agitated for 2 minutes in a plain 30 per cent hypo solution and then washed thoroughly.

The mixed intensifier is stable for approximately 30 minutes at 70° F. (21° C.).

MERCURIC CHLORIDE. — The oldest (dating back to Scott Archer in 1852) and probably the most common form of intensification consists of bleaching the silver image in mercuric chloride and then blackening it with some one of many reagents, which give varying degrees of intensification. A mercury intensifier is unsuitable for negatives that must be enlarged greatly, as it increases graininess. The blackening agent is chosen with a view to the amount of intensification desired, always remembering that the permanence of the intensified negative is sure to be impaired after it has been treated with mercury, unless the subsequent treatment reduces the mercury to either a metallic state or to that of a sulphide. The image is fairly stable after redevelopment with an organic developer, depending upon the thoroughness of the operation and the degree to which the mercuric chloride has been washed out of the emulsion (use hydrochloric acid as mentioned below), but images which have been redeveloped with sodium sulphide or ferrous oxalate (which are seldom used) are the only ones that may really be considered permanent. The mercury solution is *extremely poisonous* if taken internally, but absorption by the skin, even through cuts and abrasions, is practically harmless. Most

of the blackening solutions can be used only once, but the bleaching solution may be used repeatedly, although it is sensitive to light and should be kept in the dark or in a bottle wrapped in black paper. If negatives that are to be intensified by mercury are not thoroughly freed from hypo, insoluble stains are likely to appear. Mercury salts attack many metals, including gold and silver, so that finger rings should be taken off and watches not touched while working this process.

BLEACH FOR MERCURY INTENSIFICATION

Potassium bromide	$\frac{3}{4}$ oz.	22.5 g
Mercuric chloride	$\frac{3}{4}$ oz.	22.5 g
Water to make	32 oz.	1000 cc

Bleach the negative in this solution until the image, as seen from the back, is completely whitened, and then wash thoroughly. The gelatin retains the mercury salt very tenaciously, and the washing can be facilitated by a preliminary soaking in several baths of water acidulated with 1 part in 300 of hydrochloric acid.

The four most commonly used blackening agents are sodium sulphite; an ordinary non-staining developer; ammonia; or Monckhoven's intensifier. These afford progressively greater density in the order given.

A 10 per cent solution of sodium sulphite gives the least intensification. It has a tendency to somewhat reduce the shadow detail. This is an advantage with slightly fogged negatives, but disastrous with negatives that were originally too weak in the shadows for successful printing. Increased density cannot be obtained by repeating this process.

A non-staining developer like amidol, paraminophenol, or metol-hydroquinone gives a moderate degree of intensification, and the image is comparatively stable. The sodium sulphite in these developers has the same cutting effect on the shadows as mentioned above, but on account of its smaller concentration, the effect is less, except in the case of fine-grain developers with an excess of sulphite, which should be avoided. This process may be repeated to gain additional density. Amidol gives truer proportions between the intensified image and the original than other developers do.

A 10 per cent solution of ammonia (1 part 28 per cent concentrated ammonia to 9 parts of water) gives a very strong intensification, but it alters the gradation of tones in the final result. The image is notoriously unstable, and if it fades it cannot be brought back.

Monckhoven's intensifier, so-called from his use of it in 1879 although it was suggested first by Martin in 1854, gives extreme intensification. It reduces the shadows and adds to the density of the highlights. The image cannot be considered stable, but the great degree of intensification which it produces makes it especially suitable for black-and-white line work which is the purpose for which it is most used.

MONCKHOVEN'S INTENSIFIER

Solution A

Water	16 oz.	500 cc
Sodium or potassium cyanide	$\frac{1}{2}$ oz.	15 g

Solution B

Water	16 oz.	500 cc
Silver nitrate (crystals)	$\frac{3}{4}$ oz.	22.5 g

Cyanide is a deadly poison and should be handled with extreme care. It reacts with acid to form poisonous hydrogen cyanide gas. When discarding a solution containing cyanide, always run water to flush it out of the sink quickly. Cyanide solutions should never be used in poorly ventilated rooms.

To prepare the intensifier add the silver nitrate solution B to the cyanide solution A until a permanent precipitate is just produced; allow the mixture to stand a short time and then filter.

It is important that the silver be always added to the cyanide, and never the reverse. This should be done in small quantities, with vigorous agitation after each addition, until a precipitate is formed. The exact amount of silver needed varies with the purity of the cyanide, but the precipitate should always be formed and maintained, as otherwise the solution would have a solvent action upon the whole image. This solution will keep well if protected from light, and may be used repeatedly.

There are many other blackening agents that might be used, but most of them have no particular advantages and are not as satisfactory as the standard ones listed above, with the possible exceptions of ferrous oxalate and sodium sulphide.

Ferrous oxalate is used as a blackening agent when negatives are to be used for scientific purposes, because it gives exactly proportionate intensification. (See page 90 for formula.) If the gelatin has been hardened, the process of bleaching and blackening may be repeated as often as desired, the factor for increase of density being 1.45 for each intensification. The image is stable.

A 2 per cent solution of sodium sulphide (note that this is not sulphite) usually gives too much intensification for ordinary work. It has an unpleasant odor, and is generally avoided on account of its noxious effect upon other photographic emulsions, but it has the advantage of being one of the few blackening agents that give a permanent image. The gelatin absolutely must be hardened in the alkaline formalin bath (page 120) before it can stand this treatment.

MERCURIC IODIDE.—The mercuric iodide intensifier described by Edwards in 1879, is a very satisfactory process, and convenient because it is employed as a single bath.

MERCURIC IODIDE INTENSIFIER

Mercuric iodide	180 gr.	20 g
Potassium iodide	180 gr.	20 g
Hypo	180 gr.	20 g
Water to make	20 oz.	1000 cc

Solution may be hastened by using warm, but not hot, water. As this formula contains hypo, it is not necessary that all the hypo be eliminated from the negative after fixing, but a wash of 5 or 10 minutes is advisable. Intensification is progressive and may be watched and stopped when desired by washing in running water for 20 minutes. If only slight intensification is desired, the action may be slowed down by diluting the solution with water, so that it may be followed more closely. The solution may be used many times if stored in the dark. The image is not permanent, as it turns yellow with age, but it may be made permanent by redeveloping in an ordinary non-staining developer, or by immersion in a 1 per cent sodium sulphide (not *sulphite*) bath, after intensifying and washing.

Before redevelopment, the intensification may be reduced, wholly or in part, by immersion in 40 per cent hypo, thus affording complete control if the action has been carried too far. The intensification cannot be repeated.

Lumière and Seyewetz suggested another mercuric iodide intensifier which is quite popular.

MERCURIC IODIDE INTENSIFIER (Lumière)

Mercuric iodide	77 gr.	10 g
Sodium sulphite	770 gr.	100 g
Water	16 oz.	1000 cc

The intensified negative has a dark brown color. It is not stable, but can be made so by redevelopment.

CHROMIUM INTENSIFIER.—About 1880, Eder suggested the use of a bleach of potassium bichromate and hydrochloric acid, followed by redevelopment, as an intensifier. This process is one of the most popular of all intensifiers as it gives a permanent image, uses no poisonous chemicals, is very economical, has no tendency to stain, and may be repeated several times to gain additional density. Increase in graininess is negligible with one intensification, and only very slight after the process has been repeated several times.

CHROMIUM INTENSIFIER

Solution A, 10 per cent solution of potassium bichromate
Solution B, 10 per cent solution hydrochloric acid

These solutions are mixed in various proportions to give the degree of intensification desired. The less the proportion of acid, the greater the intensification.

For *strong intensification*, 10 parts A; 2 parts B; 100 parts water.

For *medium intensification*, 20 parts A; 10 parts B; 100 parts water.

For *slight intensification*, 20 parts A; 40 parts B; 100 parts water.

These proportions are for general guidance only, as the effect is considerably modified by the nature of the emulsion. The stock solutions keep indefinitely if the bichromate is kept in the dark, but the working solution must be mixed only at the time of use.

The work must be done in weak daylight, or in artificial light. Bleach until all the black image has disappeared from the negative when viewed from the back. Wash until all the yellow bichromate stain has been discharged, and then redevelop to finality in amidol or other non-staining developer, and finish with a final washing. On account of its cutting action, developers containing an excess of sodium sulphite should not be used.

Many people prefer to use the chromium intensifier in a single solution and vary the effect with the amount of redevelopment.

CHROMIUM INTENSIFIER (Eastman In-4)

Stock Solution

Water	32 oz.	1000 cc
Potassium bichromate	3 oz.	90 g
Hydrochloric acid, C.P.	2 fluid oz.	64 cc

For use, take 1 part of stock solution to 10 parts of water. Bleach thoroughly; then wash 5 minutes and redevelop in artificial light or daylight (not direct sunlight) in a non-staining developer, diluted 1 to 3.

Developers containing a high concentration of sulphite are not suitable for redevelopment, since the sulphite tends to dissolve the bleached image before the developing agents have time to act on it.

The degree of intensification can be controlled by varying the time of redevelopment. If the negative is not redeveloped *fully*, fix for 5 minutes, and then wash thoroughly. Fixing is unnecessary if redevelopment is thorough. Repeating the process gives greater intensification.

Dr. Boucher states that intensification cannot be repeated to advantage more than three times. Graininess of the negatives is not appreciably increased by one intensification, and only very slightly by successive intensifications.

COPPER IODIDE INTENSIFIER. — Great intensification can be obtained by the use of copper and silver, which was highly satisfactory with collodion plates, as shown by Abney in 1877, but less efficient and likely to give stains with gelatino-bromide emulsions. The following successful method worked out by G. Zelger in 1924, using copper and iodide, is particularly valuable for intensifying images so faint and ghostly that other treatments are ineffective. The density is increased three times by one intensification, and may be increased three times more by repeating the process.

COPPER IODIDE BLEACH

<i>Solution A</i>		
Copper sulphate	38 gr.	5 g
Glacial acetic acid	215 minims	28 cc
Water	8 oz.	500 cc
<i>Solution B</i>		
Potassium iodide	38 gr.	5 g
Ammonia, 22° Bé.	354 minims	46 cc
Water	4 oz.	250 cc

The bleacher is made up of 2 parts of solution A with 1 part of solution B. A yellowish deposit is formed on the negative, which is washed in running water for 20 minutes. The darkening solution is:

Silver nitrate	17.5 gr.	2.3 g
Sodium acetate	72 gr.	9.4 g
Water	16 oz.	1000 cc

Treatment in an alum bath before darkening will reduce the danger of stain. The image can be made more permanent by a 2-minute bath in 1 per cent ammonia, followed by redevelopment. If amidol is used for the redeveloper, it should be made alkaline with carbonate of soda.

INTENSIFICATION BY TONING.—Negatives may be intensified by toning, the action depending upon changing the image to a non-actinic color, rather than gaining any additional density. Two of the toners sometimes used for this purpose are the uranium (page 178) and the copper (page 179).

NEW NEGATIVES.—Many of the processes of intensification are fraught with some peril, immediate or remote, to the original negative. If the negative is of special value, it is perhaps as well to make a new negative from it, getting the desired amount of contrast in it by suitable development, without endangering the original. To make a new negative the original is printed upon another film or plate to make a positive. The "commercial" emulsions are generally used for this work because their slow speed and lack of color sensitivity make them very easy to handle and control, but any ordinary emulsion with which the worker is familiar and which he happens to have on hand can be used with proper care. The comparatively slow, fine-grained panchromatic emulsions like Eastman's Panatomic or Agfa Finopan are often used if they are the emulsion with which the worker is most familiar. The positive is developed, fixed, washed and dried, and then printed on to another film or plate for the final negative. By suitably prolonging the development, contrast can be increased up to the gamma infinity of either or both the positive and negative. Extreme contrast can be produced by using process emulsions, or by using a high contrast developer like the formula given on page 60, or both. Almost any kind and amount of control can be exercised by the processes of intensification or reduction upon either the positive or the new negative, with the advantage that the original negative is not endangered and in case anything goes wrong, work may be started anew from it.

MECHANICAL INTENSIFICATION. — A negative whose gradations are satisfactory, but which is so thin that it presents difficulty in printing, can be helped by printing through yellow or pink celluloid or a filter of those colors. A filter can be made by fixing out an unexposed plate or film, washing it, and then dyeing the gelatin with sufficiently diluted dye. Agfa's preparation known as New Coccine is ideal for this purpose, but any commercial dye will do. Alternately, a wash of the dye over the whole negative may be used, but it requires considerable dexterity to make it even. Local intensification is easily accomplished by applying the dye with a brush or tuft of cotton. For local work, have the brush so nearly dry that the dye dries almost instantly upon application. If the dye is flowed on, it will dry with a hard edge. The edges of the area treated can be softened by rubbing with a tuft of dry cotton as soon as the dye is applied. Better results are usually obtained by building up density by repeated applications of a weak dye, rather than by using a strong concentration of color. There is an advantage in working on the back of the negative when applying dyes for intensification. The dye is more easily removed if that should be necessary on account of applying too much, or because it has overrun the desired limits, and the edges of the areas that have been worked upon are softened when printing through the thickness of the negative.

CHAPTER VIII

REDUCTION

Overexposed negatives that are dense and lacking in contrast, and negatives that are too contrasty, either on account of the subject matter or from overdevelopment, can be improved by reduction, which consists of converting part of the silver of the image into a compound which can be dissolved. This can be done as soon as the negative has been removed from the wash water after development and fixation, if the gelatin has been hardened enough to withstand the subsequent operations, but it is safer to dry the negative and reduce it later. The hardening bath mentioned on page 120 is another wise precaution. In order that a reducer may act uniformly, it must be able to penetrate all parts of the gelatin at the same speed, and a dry negative should first be soaked in water until the gelatin has swollen uniformly, which may take several hours, and it should be thoroughly washed when reduction is complete. Reducers vary greatly in their action, and it is necessary to select the type of reducer best suited to obtain the result desired.

TYPES OF REDUCER. — *Subtractive, cutting, or superficial* reducers remove an equal amount of silver from all parts of the image, thus increasing contrasts. They are used for overexposed and fogged negatives, and for local reduction. If their action is allowed to continue long enough, the lighter parts of the negative will be entirely removed. For this reason they are used to clear up the transparent parts of line negatives.

Proportional reducers remove from each density of the image an amount of silver directly proportional to the total amount. Their action is thus directly opposite to the process of development, and they are used to correct too great contrast caused by overdevelopment.

Superproportional reducers remove a greater proportion of silver from the denser parts of a negative than from the thin parts, and they are used to correct extreme contrast caused by overdevelopment of a contrasty subject.

FARMER'S REDUCER. — Probably the most generally used reducer is the subtractive, named for Howard Farmer who introduced it in 1884.

FARMER'S REDUCER (Eastman R-4a) (For correcting overexposed negatives)

Stock Solution A

Water	16 oz.	500 cc
Potassium ferricyanide	1½ oz.	37.5 g

Stock Solution B

Water	64 oz.	2000 cc
Sodium thiosulphate (Hypo)	16 oz.	480 g

For use take stock solution A, 1 ounce (30 cc), stock solution B, 4 ounces (120 cc), and water to make 32 ounces (1000 cc). Add A to B, then add the water.

Pour the mixed solution at once over the negative to be reduced. Watch closely. The action is best seen when the solution is poured over the negative in a white tray. When the negative has been reduced sufficiently, wash thoroughly before drying.

Solutions A and B should not be combined until they are to be used. They will not keep long in combination.

The mixed solutions have a lemon-yellow color, and experienced workers usually mix them by eye, pouring enough of the ferricyanide into the hypo to give a pale yellow or a stronger color, thus varying the strength of the solution as desired. The maximum cutting effect is obtained with strong solutions, the weaker solutions tending more toward proportional reduction.

The tray should be rocked continuously when using this or any other reducer, to prevent uneven markings. The action is slowed if the solution is unduly cold. The reducer will be exhausted by about 5 minutes' use, and, if reduction is not complete by that time, it should be thrown away and replaced by fresh. The cutting action accelerates after it has started, and, especially with strong solutions, the negative should be flushed with plenty of water, preferably under a tap, just before it appears to be sufficiently reduced, otherwise the solution still in the gelatin will continue the reducing action farther than desired.

For a two-solution formula for Farmer's reducer, which acts proportionally, see page 133.

It has often been stated that the reduction of negatives with ferricyanide and hypo may be done immediately after the negatives are taken from the fixing bath after briefly rinsing off the excess of hypo, or by adding some ferricyanide solution to a portion of the fixing bath diverted for the purpose, but such methods are very liable to cause stained negatives. The hypo should be a fresh solution that has not been used for any other purpose, and not an old acid hypo bath contaminated with chemicals.

Another subtractive reducer, which is a modification of Farmer's reducer, is the following suggested by Haddon. It has the advantage of keeping well, and does not stain.

Potassium ferricyanide	77 gr.	10 g
Ammonium sulphocyanide	154 gr.	20 g
Water	16 oz.	1000 cc

If this reducer leaves a white deposit, it can be removed by dipping in hypo and then washing.

IODINE-CYANIDE REDUCER (Eastman).—A very powerful subtractive reducer is made from a solution of iodine in potassium iodide, to which potassium cyanide has been added to dissolve the silver iodide formed during

reduction. To make up a reducer, dissolve 5 parts iodine crystals in 100 parts of a 10 per cent solution of potassium iodide. Then dissolve 1 part of sodium or potassium cyanide in 10 parts of the iodine-iodide solution and make up to 100 parts with water. The activity of the reducer may be decreased by diluting with water.

Wash thoroughly after the reduction treatment. Negatives should preferably be hardened with the formalin hardener (page 120) previous to the treatment.

Cyanide is a deadly poison and should be handled only in a well ventilated room. Solutions containing cyanide should never be discarded in a sink containing acid, or poisonous hydrogen cyanide gas will be formed. The sink should be well washed out with water after discarding the cyanide solution.

CERIC SULPHATE.— This reducer was introduced by Lumière and Seyewetz in 1900.

CERIC SULPHATE REDUCER

Water	3 oz.	200 cc
Sulphuric acid	30 minims	4 cc
Add:		
Ceric sulphate	77 gr.	10 g
Stir until dissolved, then add:		
Water to make	16 oz.	1000 cc

For use, mix 1 part with 9 parts of water. This reduces the contrasts, and the negatives should be well soaked in water before immersing in the reducer. For overexposed, very dense negatives, mix the above stock solution with an equal volume of water, and immerse the negative dry. Care must be exercised, as the action is very rapid. A gelatin relief is formed during reduction. There is no liability to stain.

COPPER REDUCERS using potassium bromide and hypo with ammonia were suggested by Carey Lea and Howard Farmer, but the following greatly improved formula for a subtractive reducer is by W. T. Smith (1916).

CUPRIC SULPHATE REDUCER

Cupric sulphate	284 gr.	37 g
Salt	284 gr.	37 g
Water	16 oz.	1000 cc

When dissolved, add ammonia until the precipitate is dissolved and a clear, deep blue solution is formed. When ready to use, add:

Hypo	1 oz., 21 gr.	458 g
Water	16 oz.	1000 cc

It may be necessary to restrain the action by further dilution with water. This reducer keeps well and its action is similar to Farmer's. If blue stains occur, they may be removed by the use of a 0.02 per cent solution of sulphuric acid.

PERMANGANATE REDUCER.—As noted by R. Namias in 1899, a very weak, acidified solution of permanganate makes a very economical subtractive reducer.

PERMANGANATE REDUCER

Solution A

Potassium permanganate	1½ oz.	50 g
Water (hot) to make	32 oz.	1000 cc

Solution B

Water (cold) to make	32 oz.	1000 cc
Sulphuric acid	1½ oz.	50 cc

For regular use, take 1 part solution A, 2 parts solution B, and 64 ounces of water. Equal parts of solutions A and B and 64 ounces of water make a more proportional reducer.

This reducer leaves a brown stain which is removed by a plain or acid hypo bath, or by a 5 per cent solution of sodium bisulphite, or by the following solution:

Sodium sulphite	576 gr.	75 g
Oxalic acid	230 gr.	30 g
Water to make	16 oz.	1000 cc

Negatives to be reduced by this formula must be completely free from hypo. A hypo bath may be used to stop the action of the reducer. To insure even action of the reducer, the negative must be thoroughly soaked before the process is commenced. If a dry negative is put into this reducer it is likely to attack the highlights first, and cause a reduction of contrast.

The permanganate solution must be kept in the dark, which is easily accomplished by wrapping the bottle in black paper.

BELITZSKI REDUCER.—A reducer intermediate in its results between the subtractive and the proportional reducers was proposed by Belitzski in 1883. As modified by Crabtree and Muehler in 1931, it makes a very useful reducer which decreases contrast, but in a lesser degree than a true subtractive reducer, so that it is especially valuable for correcting negatives which have been both overexposed and overdeveloped, resulting in negatives which are both dense and contrasty.

MODIFIED BELITZSKI REDUCER (Eastman R-8)

Water (about 125° F.) (52° C.)	24 oz.	500 cc
Ferric chloride (crystals)	365 gr.	25 g
Potassium citrate	2½ oz.	75 g
Sodium sulphite	1 oz.	30 g
Citric acid	290 gr.	20 g
Sodium thiosulphate (Hypo)	6¼ oz.	200 g
Water to make	32 oz.	1000 cc

Sodium citrate should not be used in place of potassium citrate because the rate of reduction is slowed up considerably.

Use the reducer solution full strength for maximum rate of reduction. Treat the negatives for 1 to 10 minutes at 65° to 70° F. (18° to 21° C.). Then wash thoroughly. If a slower action is desired, dilute 1 part of the solution with 1 part of water.

This is the only known single-solution reducer which keeps well in a tank.

PERMANGANATE PROPORTIONAL REDUCER.—The standard proportional reducer for correcting overdevelopment is made by combining subtractive and superproportional reducers, as suggested by Huse and Nietz in 1916.

PROPORTIONAL REDUCER (Eastman R-5)

(For correcting overdeveloped negatives)

Stock Solution A

Water	32 oz.	1000 cc
Potassium permanganate	4 gr.	0.3 g
Sulphuric acid (10 per cent solution)	$\frac{1}{2}$ fluid oz.	16 cc

Stock Solution B

Water	96 oz.	3000 cc
Ammonium persulphate	3 oz.	90 g

To make a 10 per cent solution of sulphuric acid, take 1 part of sulphuric acid, C.P., and add it to 9 parts of water, slowly with stirring.

Use 1 part solution A to 3 parts solution B. After reduction, clear in 1 per cent sodium bisulphite and then wash thoroughly.

FERRICYANIDE AND HYPO.—Another proportional reducer is suggested by C. Welborne Piper.

FERRICYANIDE-HYPO REDUCER

Solution A

Potassium ferricyanide	1 oz., 138 gr.	75 g
Ammonium bromide	1 oz., 138 gr.	75 g
Water	16 oz.	1000 cc

Solution B

Hypo	$6\frac{1}{2}$ oz.	375 g
Water	16 oz.	1000 cc

Use 1 part of solution A to 8 parts of solution B. If only slight reduction is needed, use 1 part of solution A to 4 parts of solution B. Negatives should be thoroughly washed before reducing. Both the A and B solutions will keep well.

QUINONE.—Lumière and Seyewetz in 1910 proposed a quinone reducer which acts almost proportionally, but which forms a stain that is sometimes difficult to remove.

QUINONE REDUCER

Water	16 oz.	1000 cc
Quinone	38 gr.	5 g
Sulphuric acid	154 minims	20 cc

As soon as the desired degree of reduction has been attained, immerse the negative in a 10 per cent solution of sodium bisulphite for a few minutes, then wash thoroughly and dry.

Sodium quinone sulphonate may be substituted for quinone by doubling the quantity. The clear, yellow solution turns brown even in the dark. Reduction does not start until the solution has penetrated the film of emulsion, which usually takes a few minutes. The negatives should be thoroughly washed.

PERMANGANATE AND AMMONIUM SULPHOCYANIDE. — Gevaert gives a proportional reducer using permanganate and ammonium sulphocyanide.

PROPORTIONAL REDUCER (GR-3)

<i>Solution A</i>		
Water to make	16 oz.	500 cc
Potassium permanganate	2 gr.	0.1 g
Concentrated sulphuric acid	12 minims	1 cc
<i>Solution B</i>		
Ammonium sulphocyanide	190 gr.	12.3 g
Water to make	16 oz.	500 cc

Use equal parts of solutions A and B.

The time in the reduction bath varies from 1 to 3 minutes, according to the effect desired. After sufficient reduction has been obtained, bathe in a 1 per cent solution of potassium metabisulphite, and wash well.

TWO-SOLUTION FARMER'S REDUCER. — Farmer's reducer also may be used as a two-solution formula by treating the negative in the ferricyanide solution first and subsequently in the hypo solution. This method gives almost proportional reduction and corrects for overdevelopment. The single-solution Farmer's reducer gives only cutting reduction and corrects for overexposure (see page 128).

TWO-SOLUTION FARMER'S REDUCER (Eastman R-4b) (For correcting overdeveloped negatives)

<i>Solution A</i>		
Water	32 oz.	1000 cc
Potassium ferricyanide	$\frac{1}{4}$ oz.	7.5 g
<i>Solution B</i>		
Water	32 oz.	1000 cc
Sodium thiosulphate (Hypo)	$6\frac{3}{4}$ oz.	200 g

Treat the negatives in solution A with uniform agitation for 1 to 4 minutes at 65° to 70° F. (18° to 21° C.), depending on the degree of reduction desired. Then immerse them in solution B for 5 minutes and wash thoroughly. The process may be repeated if more reduction is desired. For the reduction of general fog, 1 part of solution A should be diluted with 1 part of water.

SUPER-PROPORTIONAL PERSULPHATE REDUCER. — There are very few reducers which act super-proportionally, and the one most used is ammonium persulphate which was recommended by Lumière and Seyewetz in 1901. Its action is disturbed by the presence of chlorides, iron, or other impurities. Distilled water should be used in compounding it, as it may refuse to work with water that is heavily chlorinated, or that contains other impurities.

PERSULPHATE REDUCER (Eastman R-1)
(For overdeveloped negatives of contrasty subjects)

Water	32 oz.	1000 cc
Ammonium persulphate	2 oz.	60 g
Sulphuric acid, C.P.	$\frac{1}{4}$ dram	3 cc

For use take 1 part of stock solution and 2 parts of water. When reduction is complete immerse in an acid fixing bath for a few minutes, then wash.

The action is slow at first, but increases in speed as the persulphate converts silver into silver sulphate which accelerates the action. The action should be stopped a little before the desired effect has been obtained, by plunging the negative, without rinsing, directly into the acid hypo.

FERRICYANIDE AND BROMIDE. — Contrast may be lessened to any degree by bleaching and then redeveloping to any desired extent, as in the following Agfa formula.

FLATTENING REDUCER

Potassium ferricyanide	1 oz., 75 gr.	35 g
Potassium bromide	$\frac{1}{4}$ oz., 40 gr.	10 g
Water to make	32 oz.	1000 cc

After bleaching and washing for 3 or 4 minutes, redevelop to desired density and contrast in any ordinary metol-hydroquinone developer and fix and wash in usual manner. Conduct operation in subdued light.

HARMONIZING NEGATIVES. — Eder, in 1881, suggested a process known as harmonizing harsh negatives, which consists in bleaching and partial redevelopment resulting in intensifying the lighter densities and reducing the heavier. This process is very effective for reducing harsh contrasts, especially if halation is present.

BLEACHING SOLUTION

Hydrochloric acid	230 minims	30 cc
Potassium bichromate	77 gr.	10 g
Alum	384 gr.	50 g
Water	16 oz.	1000 cc

When the image is bleached completely through to the support, wash out all yellow bichromate stain, and then redevelop with a slow-acting developer, such as metol or hydroquinone used at about one-quarter the usual strength. Development should be continued until, on examination of the negative from

the back, it is seen that the shadows and halftones are fully developed, while the highlights still show some white silver chloride. Fix and wash as usual. The silver chloride that has not been completely redeveloped is dissolved in the fixing bath. As the final density of the highlights depends upon the extent of redevelopment, complete control is afforded.

The following modified bleacher may be used:

Chromic acid	38 gr.	5 g
Potassium bromide	77 gr.	10 g
Water	16 oz.	1000 cc

The method of using is the same as above. To hasten the removal of the yellow stain, apply a 2.5 per cent solution of potassium metabisulphite or sodium bisulphite.

Another bleacher, suggested by Stolze, is:

Potassium bromide	38 gr.	5 g
Cupric sulphate	38 gr.	5 g
Water	16 oz.	1000 cc

Redevelop with metol. Fixing may be omitted.

LOCAL REDUCTION is obtained by applying a reducer (usually Farmer's) with absorbent cotton for larger areas or a brush for smaller areas, directly on to the part that it is desired to reduce. The work is preferably done close to a running faucet under which the negative can be quickly plunged to stop the action of the reducer if it gets out of hand or shows signs of spreading to other parts of the negative. When skies are being reduced or removed, it is convenient to support the negative on a sheet of glass in a slanting position over a tray of water, with the sky on the lower side, so that the surplus reducer will flow into the water and not overrun on to other parts of the negative. Local reduction can be performed by protecting with a coat of varnish the parts that are not to be reduced, and then immersing the whole negative in the reducer for its action upon the unprotected parts.

MECHANICAL LOCAL REDUCTION. — This method, which is rather dangerous except in expert hands, consists in local attrition of the gelatin by friction, with a piece of chamois leather or a wad of cotton moistened with denatured alcohol. Another abrasive, suggested by Baskett, consists of a mixture of equal parts of terebene, olive oil, and metal polish. This is used with chamois leather or cotton, and acts more quickly than alcohol. After its use the negative should be rubbed with benzol, gasoline, or carbon tetrachloride to remove the grease. Some commercial metal polishes may be used without any admixture, but, after shaking well, they should be allowed to stand for a few minutes for the coarser particles to settle. Abrasive pastes specially prepared for use on negatives are on the market, also pencil-like sticks of abrasive material which may be brought to a point and applied to the nega-

tive. Fine-spun glass in a special holder has been used for this purpose. An expert retoucher can reduce density in a negative by gently shaving off the emulsion with a knife or etching tool, but this requires considerable practice.

NEW NEGATIVES. — The process of making a new negative to obtain intensification, mentioned on page 126, can be used equally well for reduction. Give a sufficiently long exposure to print through the densest part of the original negative, and remember that contrast can be controlled by the length of development both of the positive and the new negative if necessary, and that the processes of intensification and reduction can both be practiced upon them, affording practically unlimited control without danger to the original negative.

MASKING WITH SUPPLEMENTARY POSITIVES. — With negatives that are to be used for projection printing, contrasts can be lessened by making a positive from the negative, developing it very lightly, and then binding it in contact with the negative and printing through both at the same time. The degree of contrast is controlled by the length of development of the positive. This process is also called *masking*.

CHAPTER IX

PROJECTION PRINTING

Prints made by projection are usually enlarged, but with suitable equipment they can also be made either the same size as the negative or smaller. Projection printing, even when no change in image size is contemplated, offers some advantages over contact printing on account of the ease with which control can be exercised in holding back or overprinting parts of the negative, or in correcting distortion.

EQUIPMENT. — The essentials for projection printing are a means of illuminating the negative evenly; a lens so mounted that it can be focused; and an easel or other device for holding the paper flat. The planes of the negative, the lens, and the easel must be parallel to insure a sharp image. Enlargers are made to operate either horizontally or vertically. Vertical enlargers offer some conveniences in operation, but the size of the enlargement is limited by the ratio between the height of the room and the focal length of the lens.

LIGHTS. — Enlargers operate by either condensed or diffused light, each of which have both advantages and disadvantages.

Condensing light systems are usually formed by placing a pair of plano-convex lenses, with their convex surfaces facing each other, between the light source and the negative. The diameter of the condensing lenses must be greater than the diagonal of the negative, so that it will be fully covered. Theoretically, with a condensing system a point source of light is focused by the condensers at the nodal point of the projection lens. In practice, the light source must be greater than a point, and the focusing allows some latitude, but the focus must be changed by moving the light when making any great changes in the size of the enlargement. A Mazda lamp is often used for the light source. An electric arc gives greater efficiency because it more closely approximates the theoretical point source, but it also gives more heat, which may buckle the film with prolonged exposure. The heat from an illuminating system is often a serious problem in projection printing, especially when using arc light or Photoflood bulbs, unless the problem has been properly taken care of in the construction of the enlarger. Lamp-houses should be large, and well ventilated, and a sheet of heat-absorbing glass is often fixed in front of the light to protect the negative as well as the lens, which may suffer if the heat is great enough to melt the balsam that unites the elements. A buckled film may be flattened by careful work in a dry-mounting press, or with an electric iron used over a sheet of blotting paper,

in each case being careful not to apply enough heat to melt the emulsion of the negative. Condensing systems make a more contrasty print than would be afforded by a contact print from the same negative, and they also exaggerate the effect of blemishes and superficial scratches on the negative. Condensed light also projects a sharper image than that made by diffused light.

The source of *diffused light* may be daylight or artificial. Daylight affords few advantages and it is so uncertain, varying not only from day to day, during the course of the day, or even within a few minutes, that it is very difficult to work with, and is seldom used.

The principal diffused artificial lights used are gaslight, Mazda, mercury vapor, argon gas, and fluorescent lamps. Gaslight, as generally used in incandescent mantles, is so hot that it is inconvenient for the worker and dangerous to the film, and is seldom used unless other light sources are unavailable. Mazda lamps are by far the most common light source used in enlargers. The amount of light that they furnish is controlled by the wattage of the bulb; whether it is clear glass, frosted, or opal; and by the type of reflector used behind it. Photo-flood lamps, or lamps overloaded because made for a lower voltage than that in use, give an intense light of strong actinic value for enlarging. They generate considerable heat and have a short life, during which the efficiency of the lamp steadily decreases until near its end its value is about one-third as great as when it was new, thus making it a constant problem to secure correct exposure. Mercury vapor and argon gas give a strongly actinic light, resulting in short exposures, and they generate very little heat, but their visual quality is so low that difficulty is sometimes experienced in focusing dense negatives. This can be overcome, as shown on page 140. Fluorescent lamps, which furnish light closely similar to daylight, and with little heat, are very satisfactory.

When using other than the "cold" lights, suitable provision must be made in a lamp-house for ventilation, so that it will not overheat. Excessive heat buckles film so that it cannot be held in focus, and in extreme cases may even melt the emulsion, especially if the negative has not been hardened. Extreme heat may also melt the balsam cement in the projection lens.

Artificial light is so strongly localized that it needs additional diffusion to even it up. This is usually secured by placing a sheet of opal glass or one or more sheets of groundglass between the light and the negative. The area of the glass used for diffusion must be greater than that of the negative, so that it will be fully covered. In using groundglass, the diffusion is sometimes graduated by having the grinding blended gradually from the center until it merges into almost clear glass around the edges so that the diffuser is more transparent at the edges than at the center, thus compensating for the greater intensity of light at the center. The same effect may be secured by placing an unexposed plate or film in the position of the groundglass and giving it a quick flash of the enlarging light. After a short development, the negative

is fixed and washed and will be found to have been fogged in proportion to the intensity of the light on any given part of its area. If this negative is then replaced in front of the light source as a diffuser, it will even up the intensity of the light. Several Mazda bulbs can be used in the lamp-house, so arranged that they give a fairly even illumination which can often be fully corrected by the use of one sheet of groundglass. It is desirable to use as little diffusion as possible as its obstruction to the light lengthens the exposure. Groundglass obstructs the light less than opal glass.

The efficiency of any light is greatly increased by the use of reflectors, preferably parabolic with the light source placed near the principal focus of the paraboloid. With luminous tubes (argon and mercury) an efficient reflector is made by placing a sheet of crinkled tin foil behind the tube.

LENSES.—It is an axiom that the lens that took the picture can also enlarge it. It is necessary only that the enlarging lens cover the whole negative, or that part of it that is to be enlarged. Anastigmat lenses, however, possess the valuable feature of a flat field at large apertures, and so are ideal for enlarging. While rapid rectilinear lenses can be used, their small aperture increases exposure time to inconvenient lengths, and they never give definition over the entire field equal to that furnished by anastigmats. As practically all enlarging work is done at less than infinity focus, a lens of slightly less focal length than that necessary to cover the negative in taking the picture can be used for enlarging, thus effecting some saving in operating space. Interchangeable lenses of short focus are convenient when extreme enlargements have to be made from small parts of negatives. Lenses have their most critical correction at one given extension, and for convenience in ordinary work this is usually calculated for infinity. Lenses especially made for enlarging have their most critical correction at an extension greater than infinity, at a point nearer the distance at which they will usually be operated, and for this reason are advantageous in scientific work requiring the utmost precision, but for any ordinary work a regular anastigmat lens answers every requirement.

Negatives made with a soft focus lens and sharply enlarged with an anastigmat, preserve in the print the exact soft focus quality of the original. Soft focus lenses are often used for enlarging negatives made with an anastigmat, to introduce some degree of diffusion into the print. It must be remembered that while a soft focus lens in taking a picture spreads the light, a soft focus lens when enlarging a sharp negative has the opposite effect. It spreads the lighter parts of the *negative* resulting in more apparent diffusion in the darker tones of the print. Pleasant effects can be secured when using a soft focus lens for enlarging by starting the exposure with the lens stopped down to a point where it will give an image that is practically sharp, and finishing the exposure with the lens opened more widely. This procedure will give fairly firm drawing with a pleasing degree of diffusion. Diffusion is also secured

by various devices like interposing crumpled cellophane, or a transparent mesh as of silk, between the lens and the print, and different degrees of diffusion can be secured by varying the distance between the print and the diffusing medium. There are also several commercial devices like diffusion discs and transparent screens which can be slipped over the lens.

A sharp negative can be enlarged to give apparently the same effect as if the original had been taken with a soft focus lens, by making a positive, either by contact or by projection with a sharp lens, and making from this positive a new negative by projection with a soft focus lens. This negative will then have practically the same quality as if it had been made by a soft focus lens, and if enlarged with an anastigmat lens, the true soft focus quality will be preserved.

Stops on the lens are primarily used during enlargement to control the amount of light projected, thus regulating the exposure. With an anastigmat lens, if all parts of the apparatus are parallel, there is no necessity for stopping down to secure definition and the lens can be used at full aperture to shorten the exposure. An exception must be made in the case of certain anastigmat lenses which are not fully sharp at their widest opening, as in some of the short focus lenses of large aperture used in miniature camera work. These must usually be stopped down to about $f:3$ for critical definition.

If short focus lenses are stopped down too far, the depth of field will be increased until it includes the groundglass, if any is used, and the projected image of it will ruin the print.

If the elements of the enlarging system are not absolutely parallel to each other, some part of the enlargement will be out of focus. If this is slight, sharpness can be secured by slightly stopping down the lens.

FOCUSING. — When critical focus cannot be secured visibly, various aids can be used. An ordinary reading glass, held at such an angle that the projected light does not pass through it, is usually sufficient. It is easier to secure sharp focus by comparing at different extensions of the lens the relative blackness of a given part of the image on the screen than by trying to observe detail.

A cap with an opaque bar across its center slipped over the lens is an aid in quick focusing. When this cap is in place, light cannot pass through the center of the lens but does pass along each side of the bar, forming a duplicate image on the screen if the negative is slightly out of focus. As focusing progresses, the two images approach each other and coincide when the focus is sharp. Instead of the cap, a strip of metal can be bent so that it will clamp over the lens and achieve the same result. For greatest efficiency, the width of the bar should be slightly less than half the diameter of the lens.

With very dense negatives, when it is impossible to be sure of critical focus, a special negative may be used for focusing only. When the original negative has been focused as sharply as possible to the desired size, it is removed from

the carrier and the special negative inserted in its place and focused critically. The focus-negative is then removed and the original negative replaced in the carrier and the exposure made with confidence that the focus is as sharp as it is possible to get it. This focusing negative may be a thin negative with critical detail which is easily seen upon the screen, or it may be an old, dense negative upon which several scratches have been made through the emulsion with a needle. The scratches are very easy to focus upon. There are also commercially obtainable negatives consisting of sharply defined lines and dots which are made for this purpose.

SCALE ENLARGEMENTS.—Making an enlargement to exact scale can be done by calculation (see page 22), or by measurement. It is difficult to measure the exact size of an object upon a negative and any slight error in this respect is greatly magnified in the final result. A better way is to make two scratches on the negative, through the emulsion, a fixed distance apart, and outside the area that is to be used. The distance between these scratches upon the screen can be readily measured and the degree of enlargement calculated from them. To avoid defacing the negative, or for convenience if much of this work is to be done, a special negative can be prepared. Measure off an exact inch, or as many inches as the negative will accommodate, and scratch these measurements sharply through the emulsion with a needle. Any desired magnification can then be easily calculated by measurement upon the easel. After this is done, the negative that is to be enlarged is substituted in the carrier, and the exposure made without changing the position of lens or easel. For table of distances in enlarging and reduction, see page 146.

TEST FOR PARALLELISM.—The parallelism of the parts can be conveniently tested by accurately cutting out a square of black paper and pasting it upon a transparent film which has been fixed and washed without exposure. When this square is projected upon the easel, its four sides can be measured, and if they are not equal it will show that some part of the apparatus is out of true. Great care must be exercised in making the original square as accurately as possible, and to facilitate this accuracy, it should be made as large as the negative will accommodate and still show a clear space around it.

EXPOSURE is conveniently controlled by means of a safe, orange-colored filter in a cap over the lens. With the image projected through this filter, the paper can be placed in exact position without danger of fogging it. The cap is then removed to make the exposure. This must be done without causing the apparatus to vibrate, or a blurred image will result. If there is danger of this on account of lack of rigidity in the apparatus, it is better to shut off the light, remove the cap, wait until any vibration has ceased, and then make the exposure by turning on the light for the required time. A foot switch to control the light is a convenience, as it leaves both hands free for dodging the print up to the end of the exposure. The orange filter may be mounted in a carriage so that it will run freely in front of the lens and exposures can be

made in this way with little danger of vibration. The filter should be tested to make sure that it is safe, by exposing through it on the easel a sheet of the fastest paper that is used, for the length of time that it takes to adjust the paper when making a print. Have half of the printing paper covered with a sheet of black paper, and if, on development, there is no visible difference between the two halves, the filter is safe. Even a slight degradation from this cause may make an appreciable difference in the quality of the print.

Exposures are sometimes timed by counting seconds, at which a person may become quite adept after a little practice, but it is an unreliable method, and tedious if the exposure runs to many seconds. A clock with a large second hand, clearly illuminated by a safelight, is a better method. If the exposures run to minutes, as they sometimes do with excessive enlargements on slow papers, an interval timer which rings a bell at the expiration of a set time can be used. A variation of the process of counting seconds is to use a metronome and count its ticks, but any counting method is distracting, and the count is likely to be lost if dodging the print requires much attention.

For calculation of exposure time, see page 153.

NEGATIVE HOLDERS. — Film is usually sandwiched between two pieces of glass which hold it flat in the carrier of the enlarger while it is being projected. If lenses of large aperture are used for projection, it is necessary that the film be quite flat so that all parts of it can be focused sharply at the same time. A mask of thin, opaque paper can be included between the glasses to screen off all parts of the negative not included in the picture, thus preventing much extraneous light in the darkroom, which might be reflected back to the easel and degrade the paper. All surfaces of the glass used for holding negatives must be spotlessly clean, as any dirt on the glass will show on the print. Glass can be cleaned with soapsuds, ammonia and water, or alcohol and water. Preparations used for cleaning windshields are excellent. Or, moisten the glass with water, rub it with charcoal, and polish with a dry cloth. In obstinate cases, use one of the following solutions.

GLASS CLEANER

Water	20 oz.	1000 cc
Potassium bichromate	1 oz.	50 g
Sulphuric acid	$\frac{1}{2}$ oz.	25 cc

Immerse the glass and scrub with an old toothbrush or mop made by tying some rags on a stick, turning the glasses over with a stick, as the solution bites the fingers. Rinse in cold water, then in hot water, and dry.

Or make a thin cream of

Tripoli	8 oz.	500 g
Denatured alcohol	8 oz.	500 cc
Ammonia	8 oz.	500 cc

Rub on with a cloth, polish with a clean cloth, finish with filter paper.

Too much polishing of the glass will cause it to be electrified, in which condition it will attract dust and lint from the air, sometimes in such quantities as to make work practically impossible, or at any rate entailing an immense amount of spotting upon the negative. If the enlarger is made of metal it usually has, or can be provided with, a binding post from which a wire can be attached to a water pipe or other suitable ground to discharge the electrical charge. Lacking this attachment, or if the enlarger is built of wood, the electricity can sometimes be discharged by touching the glass plates to the ground. Relief can also be had by boiling water in an open receptacle in the darkroom to increase the humidity of the air. With cold lights, or if the regular light does not generate too much heat, glass holders can be dispensed with and the film can be held sufficiently flat between plates of brass or other suitable metal, with cut-out openings the size of the area of the film that is to be used. These metal plates save much labor and annoyance in cleaning glass.

PAPER HOLDERS. — To ensure accurate focus over the whole enlargement, it is quite essential that the paper be as flat as the negative during enlargement. With horizontal enlargers the paper may be held on the upright easel by pushpins or adjustable spring clips which grip its edges and hold it flat. The easel may be fitted with a shelf with vertical adjustment and the paper held in a printing frame which sets on the shelf. The paper will usually lie flat enough in the frame without the use of glass. If masks are used to make a white border on the print, glass will have to be used to obtain sufficient pressure to keep the mask and the paper in contact.

Single-surfaced gelatin letter duplicators, commercially obtainable in stationery stores, make convenient easels. A sheet of paper laid on the gelatin adheres to it and is held flat during printing, and is then easily stripped off. The regular letter size will handle anything up to 8 by 10 inches. For larger sizes, the refilling compound can be bought in bulk, melted according to directions on the container, and then cast in shallow tins to any dimensions required. By this method, paper can be printed clear to the edges.

Instead of using the commercial gelatin duplicators, a mixture for the same purpose may be made as follows:

ADHESIVE FOR EASEL

Water	24 oz.	700 cc
Gelatin	1½ oz.	50 cc
Karo corn syrup	2 oz.	55 g
Glycerin	2 oz.	60 cc
Water to make	30 oz.	900 cc

Let the gelatin soak for about an hour in the 24 ounces (700 cc) of water to which the syrup and the glycerin have been added, then warm the mixture up to about 120° F. and stir until thoroughly dissolved. Then add

water to make 30 ounces (900 cc). In a separate container dissolve 15 grains (1 g) of chrome alum in 3 ounces (100 cc) of water, and add to the first mixture.

Strain through a fine-mesh cloth and apply liberally to the easel, which must be supported in a horizontal position so that the mixture will set with a flat surface, which will take about 24 hours.

With vertical enlargers, some kinds of paper will lie flat enough on the horizontal easel without being clamped. Most papers, however, have so much curl that they have to be held down by pushpins, or by weights placed along their edges, or by a sheet of plate glass placed over the paper. Printing frames can also be used for this purpose. Masking frames, with arms of thin metal, can be obtained commercially. These hold the paper flat, and make a white border around paper of any size.

BORDERS.—The protection afforded by the rabbet of a printing frame makes a narrow white border on a print. Wider white borders are made by placing a mask of opaque paper in the frame between the glass and the printing paper. Black borders can be made by placing an opaque card over the print, before development, in such a position that it exposes two adjacent margins of the print to a white light that is flashed on. The card is then readjusted to expose the other two margins.

COMBINATION PRINTING.—In printing clouds into a landscape from another negative, care should be taken that both the clouds and the landscape are lighted from the same direction. If necessary, the cloud negative can be reversed in the carrier so that the lighting will come right. Run tests on both negatives to learn what exposure time they need. Project the landscape on the easel to a somewhat smaller scale than the size you are going to print, and trace the outline of the skyline roughly on a card. Tear the card apart on this line and save both parts for masks in printing. During the whole of the exposure for the landscape, shade it down to the skyline with the upper part of the mask, which, being a little smaller than the image projected for printing, can be held a little in front of the print and its shadow will be just the right size for shading the sky. If it were held in contact with the print, it would show a hard line. Keep the mask moving with a slightly circular motion during the whole of the exposure. Put the orange cap on the lens, and before removing the paper from the easel, mark its outlines on an underlying, larger sheet of paper. On the edges of this paper, mark where the skyline comes on the edge of the print. Substitute the cloud negative in the carrier, and adjust it so that the skyline comes down to this mark. During exposure, shade the lower part of the print with the other half of the mask. When using a printing frame to hold the paper, the skyline can be marked upon the glass with a wax pencil before taking the landscape negative out of the carrier, and this pencil line rubbed off after adjusting the cloud negative to it. If many such prints have to be made

from the same negatives, time can be saved by binding them into permanent contact and printing both together. Since the emulsion sides of the negatives have to be in contact to secure perfect sharpness in this form of printing, the two negatives in this case will have to be lighted from *opposite* directions, and the unwanted portions of each negative bleached completely away with Farmer's reducer.

For other forms of combination printing, where an object of quite definite shape is to be introduced into another negative, as a figure into a landscape, one of the easiest methods is that of combining prints. The figure is printed to the proper scale on a light-weight paper, carefully cut out, and the edges skived down from the back, either by the use of a knife or by fine sandpaper, and the figure then pasted on to the landscape print. The edges are then blended with a little water color paint mixed to match the tone of the print, and the print is copied to make a new negative.

Another method of combination printing is by making positives of each negative, and combining them for printing a new negative. On the negative containing the figure, block out with opaque all except the figure itself. Reverse this negative in the carrier and then by projection make a positive of the size desired for the new negative. This will show only the figure with a clear background. The landscape is now projected to the corresponding size and focused. Under the orange cap on the projecting lens, a plate or film is placed in position on the easel and the positive of the figure is moved about on it until it occupies the correct position in the landscape, when it is affixed to the unexposed plate with tape or a touch of adhesive. The emulsion sides must be in contact, so the positive of the figure must have been reversed when it was made. An exposure is now made for the positive of the landscape. When this is developed it will show the landscape with a blank space where it was masked by the positive of the figure. If the figure image was not opaque enough to make this space absolutely blank, it should be made so by the judicious use of Farmer's reducer, being careful not to overrun the outlines in the reducing. The two positives so obtained are then bound up in register, and from them a new negative is printed.

The point requiring the greatest amount of care in this process is the opaqueing of the figure out of the original negative. It is best to use the opaque in a fine pen when outlining the figures. Opaque can then be worked up to this line with a brush, and the brush used for the rest of the negative.

PHOTO MURALS. — In making excessive enlargements, as for mural decoration, where the necessary space is not available for the large projection, an intermediate positive is sometimes made. Part of the magnification is secured upon this positive, taking care that the new size is not too large to be handled by available apparatus for further enlarging. The intermediate positive gives an opportunity for retouching and removing any blemishes. From this positive a new negative is made by contact, and from this the final enlargement.

TABLE OF DISTANCES IN ENLARGING AND REDUCING

Focus of lens	Times of enlargement and reduction									
	1	2	3	4	5	6	7	8	9	10
inches	inches	inches	inches	inches	inches	inches	inches	inches	inches	inches
1	2 2	3 $1\frac{1}{2}$	4 $1\frac{1}{3}$	5 $1\frac{1}{4}$	6 $1\frac{1}{5}$	7 $1\frac{1}{6}$	8 $1\frac{1}{7}$	9 $1\frac{1}{8}$	10 $1\frac{1}{9}$	11 $1\frac{1}{10}$
$1\frac{1}{2}$	3 3	$4\frac{1}{2}$ $2\frac{1}{4}$	6 2	$7\frac{1}{2}$ $1\frac{1}{8}$	9 $1\frac{1}{5}$	$10\frac{1}{2}$ $1\frac{1}{4}$	12 $1\frac{1}{7}$	$13\frac{1}{2}$ $1\frac{1}{6}$	15 $1\frac{1}{9}$	$16\frac{1}{2}$ $1\frac{1}{10}$
2	4 4	6 3	8 $2\frac{2}{3}$	10 $2\frac{1}{2}$	12 $2\frac{2}{5}$	14 $2\frac{1}{3}$	16 $2\frac{1}{7}$	18 $2\frac{1}{4}$	20 $2\frac{1}{9}$	22 $2\frac{1}{5}$
$2\frac{1}{2}$	5 5	$7\frac{1}{2}$ $3\frac{1}{4}$	10 $3\frac{1}{3}$	$12\frac{1}{2}$ $3\frac{1}{8}$	15 3	$17\frac{1}{2}$ 3	20 $2\frac{2}{7}$	$22\frac{1}{2}$ $2\frac{1}{4}$	25 $2\frac{1}{5}$	$27\frac{1}{2}$ $2\frac{1}{10}$
3	6 6	9 $4\frac{1}{2}$	12 4	15 $3\frac{3}{8}$	18 $3\frac{2}{5}$	21 $3\frac{1}{3}$	24 $3\frac{1}{7}$	27 $3\frac{1}{8}$	30 $3\frac{1}{9}$	33 $3\frac{3}{10}$
$3\frac{1}{2}$	7 7	$10\frac{1}{2}$ $5\frac{1}{4}$	14 $4\frac{2}{3}$	$17\frac{1}{2}$ $4\frac{3}{8}$	21 $4\frac{1}{5}$	$24\frac{1}{2}$ $4\frac{1}{4}$	28 4	$31\frac{1}{2}$ $3\frac{1}{6}$	35 $3\frac{1}{9}$	$38\frac{1}{2}$ $3\frac{1}{10}$
4	8 8	12 6	16 $5\frac{1}{3}$	20 5	24 $4\frac{4}{5}$	28 $4\frac{2}{3}$	32 $4\frac{1}{7}$	36 $4\frac{1}{4}$	40 $4\frac{1}{9}$	44 $4\frac{1}{5}$
$4\frac{1}{2}$	9 9	$13\frac{1}{2}$ $6\frac{1}{4}$	18 6	$22\frac{1}{2}$ $5\frac{3}{8}$	27 $5\frac{2}{5}$	$31\frac{1}{2}$ $5\frac{1}{4}$	36 $5\frac{1}{7}$	$40\frac{1}{2}$ $5\frac{1}{6}$	45 5	$49\frac{1}{2}$ $4\frac{1}{10}$
5	10 10	15 $7\frac{1}{2}$	20 $6\frac{2}{3}$	25 $6\frac{1}{4}$	30 6	35 $5\frac{5}{6}$	40 $5\frac{4}{7}$	45 $5\frac{1}{8}$	50 $5\frac{1}{9}$	55 $5\frac{1}{10}$
$5\frac{1}{2}$	11 11	$16\frac{1}{2}$ $8\frac{1}{4}$	22 $7\frac{1}{3}$	$27\frac{1}{2}$ $6\frac{3}{8}$	33 $6\frac{2}{5}$	$38\frac{1}{2}$ $6\frac{1}{4}$	44 $6\frac{1}{7}$	$49\frac{1}{2}$ $6\frac{1}{6}$	55 $6\frac{1}{9}$	$60\frac{1}{2}$ $6\frac{1}{10}$
6	12 12	18 9	24 8	30 $7\frac{1}{2}$	36 $7\frac{1}{5}$	42 7	48 $6\frac{6}{7}$	54 $6\frac{3}{4}$	60 $6\frac{2}{9}$	66 $6\frac{1}{5}$
7	14 14	21 $10\frac{1}{2}$	28 $9\frac{1}{3}$	35 $8\frac{3}{4}$	42 $8\frac{2}{5}$	49 $8\frac{1}{6}$	56 8	63 $7\frac{1}{8}$	70 $7\frac{1}{9}$	77 $7\frac{1}{10}$
8	16 16	24 12	32 $10\frac{2}{3}$	40 10	48 $9\frac{3}{5}$	56 $9\frac{1}{3}$	64 $9\frac{1}{7}$	72 9	80 $8\frac{1}{9}$	88 $8\frac{1}{5}$
9	18 18	27 $13\frac{1}{2}$	36 12	45 $11\frac{1}{4}$	54 $10\frac{2}{5}$	63 $10\frac{1}{6}$	72 $10\frac{1}{7}$	81 $10\frac{1}{8}$	90 10	99 $9\frac{1}{10}$
10	20 20	30 15	40 $13\frac{1}{3}$	50 $12\frac{1}{2}$	60 12	70 $11\frac{2}{3}$	80 $11\frac{1}{7}$	90 $11\frac{1}{8}$	100 $11\frac{1}{9}$	110 11
11	22 22	33 $16\frac{1}{2}$	44 $14\frac{2}{3}$	55 $13\frac{1}{4}$	66 $13\frac{1}{5}$	77 $12\frac{2}{3}$	88 $12\frac{1}{7}$	99 $12\frac{1}{8}$	110 $12\frac{1}{9}$	121 $12\frac{1}{10}$
12	24 24	36 18	48 16	60 15	72 $14\frac{2}{5}$	84 14	96 $13\frac{1}{7}$	108 $13\frac{1}{8}$	120 $13\frac{1}{9}$	132 $13\frac{1}{10}$

The above table gives the distances between the lens and sensitive surface and lens and negative, both for enlarging and reducing, or copying. In the former case the upper figures are the distances between the lens and sensitive surfaces, and the lower figures the distances between lens and negative. In reducing or copying these are reversed, the upper figures being the distances between the lens and object and the lower lines those between the lens and sensitive surface.

The "times" of enlargement or reduction is found by dividing the longer base of the picture by the longer base of the image. Example: a 4 by 5 negative is to be enlarged to 20 by 25, then $25 \div 5 = 5$ "times." The reverse

of this gives the "times" of reduction, example: a 5 by 7 negative is to be reduced to lantern size, then $7 \div 3\frac{1}{4} = 2\frac{2}{18}$.

The above table is calculated from the formula $D = (r + 1) f$ and $d = D \div r$, in which D = the distance from large image to the lens, d = distance of lens from small image, r = "times" of enlargement or reduction and f = equivalent focus of lens. Obviously if r and f are known, D or d can be easily found. Example: taking the above case of enlarging with a $6\frac{1}{2}$ -inch lens, we have $D = (5 + 1) 6\frac{1}{2} = 39$ inches.

On account of the difficulty in knowing what part of the lens to measure from in using the above figures, it is much more convenient, and usually accurate enough, to add the two figures and make the distance between the negative and the easel equal to their sum, and then focus the lens visually.

For a quick approximation of the distance needed to make an enlargement, multiply the focus of the lens by the times of enlargement plus 1. Thus, to make a $10\times$ enlargement with a 2-inch lens, $11 \times 2 = 22$, the distance between lens and paper. To this must be added an allowance for the distance occupied by the apparatus, including the extension of the lens which varies only slightly at large magnifications.

PRINTING CONTROL. — Local areas of an enlargement can be printed lighter than they would normally appear in relation to surrounding areas, by shading them from the action of the light during part of the exposure. If the area that is to be shaded extends to the margin of the paper, this is often done by manipulating the hands in the pathway of light so that they cast shadows of the desired size and shape upon the paper. Any area, wherever situated, can be shaded with a roughly torn scrap of opaque card or paper impaled upon a stiff wire. If the wire is kept moving all the time it is in use, it will have no effect upon the sensitive paper.

Areas can be printed darker by playing the light upon them through a hole in a card that masks the rest of the paper. A variation is a hole in a sheet of orange celluloid which protects the paper while allowing freer inspection of the work.

Whatever devices are used for controlling printing, they must be kept in motion and out of contact with the paper, to prevent hard lines showing at the margins of the manipulated area.

Printing control is useful to adapt the tonal range of negative to paper (see page 151). If the exposure scale of the paper is somewhat greater than the density range of the negative, both black and white tones can be secured upon it by giving additional printing to the shadows. If the exposure scale of the paper is too short (a contrasty paper) it can be lengthened by giving additional printing to the lighter tones which would otherwise all print uniformly white. Or, the total exposure can be lengthened so that the lighter tones print with proper gradation while the lower tones are held back for part of the exposure, so that they will not be overprinted.

COMPOSITE PICTURES are made by photographing several people, with the same lighting, preferably flat, with the heads all the same size, and giving the negatives identical development. These negatives are successively printed upon the same sheet of paper.

One of the negatives is projected on to the easel and its exposure time ascertained. Divide this time by the total number of negatives and give an exposure from each negative for that fraction of the total time, superimposing the images on the paper. Project the first negative on to a sheet of paper the same size as the printing paper, and outline with a soft pencil or crayon the head and eyes. Register marks must be made upon the easel so that this paper and the printing paper can be replaced in exactly the same position. After the first exposure has been made, replace the sketched outline on the easel and register the eyes of the second negative upon those of the first, and then put the photographic paper back and make the second exposure. All the remaining negatives are similarly registered and exposed. It is well to make each exposure slightly longer than that calculated, because the cumulative effect of intermittent exposure is never so great as that of a continuous exposure for the same length of time. Composite pictures are interesting to show predominant facial characteristics of families or groups of people with some common interest.

CHAPTER X

DEVELOPING-OUT PAPERS

While there are many methods of photographic printing which yield a visible image, the great majority of prints are made upon paper which retains only a latent, invisible image after exposure. They have to be developed, by a process very similar to that employed for negatives, to make the image visible, and for this reason are called developing-out papers to distinguish them as a class from the earlier type of paper that gave a visible image without development. Developing-out papers are fixed and washed like negatives to make the image permanent.

KINDS OF PAPER. — The three principal kinds of developing-out paper, depending upon the kind of halides, or combination of halides, with which they are coated, are *chloride* (in England called *gaslight* papers), *chlorobromide*, and *bromide*. Of these, the chloride papers are the slowest and the bromide the fastest, with the chlorobromide intermediate in speed. Any of them may be printed by contact, yielding a print the same size as the negative; or by projection by which the print can be made either the same size as the negative, or larger or smaller, at will. The chloride papers are most used for contact printing, for which their speed is best adapted. For enlarging with them, the exposure time is inconveniently long and requires an intensity of projection light not generally available. The speed of the bromide papers makes them pre-eminently fitted for enlarging, but somewhat difficult to handle for contact printing from ordinary negatives. The chlorobromides are probably most often used for projection printing. They require much more exposure time than bromide papers, which is a serious consideration in commercial establishments where production is large, but of less importance to the amateur or occasional worker. While perhaps not quite so convenient as the chlorides for contact printing, they are often used for that purpose, especially by persons who do not wish to stock a large variety of paper.

SPEED OF PAPERS. — The *absolute* speed of papers is seldom, if ever, stated by manufacturers. The characteristic curve of an emulsion on paper is so different from the curve of a negative emulsion that any comparison between them would have little value. When the speed of papers is measured, it is usually done upon the threshold value. The speed of papers varies somewhat from batch to batch of emulsion, with the climate, and with the age and conditions of storage, so that general figures are of little value.

A rough idea of the *relative* speeds of different kinds of papers may be had from the fact that if the exposure necessary for a fast bromide paper were taken as 1, other bromides would rate from 1 to about 50; chlorobromides from about 25 to 200; and chlorides from about 100 to 1000 or more. It will be seen that there is considerable overlapping of speeds between different kinds of paper, notably with the chlorides made for projection printing.

CONTRAST IN PAPERS. — Unlike negative emulsions, which can be developed at will to a wide variety of contrasts, the contrast of an emulsion on paper is fixed during manufacture, and can be altered only slightly by manipulations in development without loss of print quality. A negative works by transmitted light, and its different densities may be built up so that the lightest part will transmit perhaps 128 times as much light as the densest part. This is not an absolute figure, but probably a fair average for negatives with a long range of tones, developed to a workable gamma. Paper, on the other hand, is seen by reflected light, and contrast cannot be built up by adding density beyond the amount necessary to make the surface black. Any added deposit of silver, up to a certain amount, has a greater light-stopping power for *transmitted light*, but an object will *reflect* no less light if it is black all the way through, than if its surface alone is black.

The *absolute* contrast of all papers, if their surfaces are alike, is the same. Any photographic paper, regardless of its contrast, will give a range of tones from white to black. White and black are only approximations, because no paper will reflect all the light incident upon it, as would be necessary to produce white; and no deposit of silver can be made so black that it will reflect no light at all, as would be necessary to produce absolute black. The proportions of the incident light that are reflected by the different parts of a print depend upon the surface of the emulsion. Blacks upon a glossy paper reflect less light, and so are blacker than blacks upon a mat paper which reflects more light. On the lighter end of the scale, glossy papers reflect *more* light than mat papers. The ratio between the light reflected by the lightest and the darkest parts of a glossy print is about 20 to 1; upon a mat paper, no more than 10 to 1; with semi-mat papers ranging in between. This ratio is called the *brightness range* of papers.

This extreme of reflecting power has nothing to do with the so-called "contrast" of papers by which they are listed and sold. That contrast of paper depends upon the ratio between the least and the greatest amounts of light that will produce visible differences on the paper; between the intensity of light that will have a barely visible effect on the paper, and the intensity of light that will produce the closest approximation to black that the paper will render. This ratio is the *exposure scale* of the paper.

The terms used by different manufacturers to designate the contrast of papers have no uniformity, and no absolute meaning. In general the terms,

soft, *normal* (or *medium*), and *hard* (or *vigorous*), give some indication of the general character of the paper, but one manufacturer's "hard" may be identical in contrast with another's "normal." Some manufacturers list their softest paper as 1, and designate increasing degrees of contrast by larger numbers. But they seldom give any indication of just *how* hard or how soft the paper is. The worker must find that out for himself by the use of a sensitometric wedge, or by trial and error experience.

By exposing a paper under a sensitometric wedge the densities of which are so arranged that each successive step increases proportionally the amount of exposure given, the exposure scale of that paper is easily determined, after development of the paper, by calculating the ratio between the lightest and the darkest steps that show visible differences of tone. The same results may be secured by giving a series of increasing exposure times to a constant illumination, instead of using the sensitometric wedge, although this method is more laborious and more liable to mechanical error.

ADAPTATION OF PAPER TO NEGATIVE. — The *density scale of a negative* is the ratio between its least opaque and most opaque parts. The different opacities in a negative have different light-stopping powers, which, for convenience in calculations, are designated as *densities*, the name density being arbitrarily assigned to the common logarithm of opacity (see page 76). The densities of a negative are caused by the brightness range to which it was exposed and the degree (γ) to which it was developed. In printing, the density scale of the negative — the range of light intensities that it transmits — determines the range of exposures that will be given the paper. As the range of tones that any paper will record (its *exposure scale*), is fixed within narrow limits during manufacture, the density scale of the negative dictates what paper must be used to record all the gradations of the negative.

If a negative which transmits through its least opaque parts fifty times as much light as it does through its most opaque parts, is printed upon a paper with an exposure scale of 40, the negative gives the shadows fifty times as much exposure as it does the highlights. Yet, from the inherent character of the paper, any part of it that receives forty times as much exposure as is needed to barely tint the paper, will be black. The result will be that if the exposure is calculated to show detail in the highlights, what should have been the darker gradations will all be uniformly black, without detail, beginning with the gradation that received forty times the exposure of the highlight. Conversely, if a minimum exposure that would preserve gradations in the shadows had been given, the upper ranges would be uniformly white, without gradation, after the ratio of 40 to 1 had been exceeded. The paper is too *contrasty*, which means that its exposure scale was not long enough for the negative.

If, for the same negative, the paper had an exposure scale of 60, it would

be too *soft* for the negative. To produce a black on that paper would require sixty times as much exposure as would be necessary to tint the highlights, but the negative can deliver only fifty times as much. If the highlights approximate white, no shadow can reach black. If the shadows are printed black, the highlights are much less than white.

If the subject matter is such, as is usually the case, that the negative has recorded neither black nor white, but only a scale of tones running from light gray to dark gray, the exposure scale of the paper must be greater than the density scale of the negative, so that the lightest tone will not be rendered white, nor the darkest tone black. The same is true if the tones of the negative run only from white to some shade of gray less than black, or from black to some shade of gray less than white.

While there is a wide range of contrast in different papers, it cannot be expected that an *exact* match in range of tones can be found for every negative. In practice, for a subject that has the whole range of tones from black to white, it suffices if the range of tones in the paper is equal to, or slightly in excess of, the range of tones of the negative. If the excess is not too great, while both white and black cannot be produced upon the paper at the same time, the approximation will be close enough for ordinary practical purposes if the difference is split between the two ends of the scale. If the subject matter makes it desirable, one end of the scale can be favored at the expense of the other. Use can be made of a highlight coming next to a shadow making the shadow appear darker than it actually is. And use can be made of the relative brightness scale of different paper surfaces which change the actual value of tones. The relative value of the tones of the negative can also be altered to a certain extent by local control in printing to make them fit the exposure scale of a given paper.

The foregoing applies only to full-scale pictures which exhibit a range of tones from black to white, which is the exception rather than the rule in pictures, but its principles govern the intelligent selection of paper for any negative. Most pictures are far less than full scale, and the worker not having both whites and blacks (and often neither) to register at the same time, can key his picture by placing it anywhere he pleases, up or down the scale.

The exposure scale varies from about 1 to 5 for very contrasty papers to about 1 to 100 for soft papers. The exact range can be determined by the use of a sensitometric wedge, or by graduated exposures. As the density scale of a negative can be determined by the use of a densitometer, it is an easy matter for anyone with laboratory equipment to measure both scales and select a paper suitable to the negative. In ordinary practice, where laboratory facilities are lacking, this is usually done by actual trial and error. A negative with a normal range of tones is printed upon a normal paper. A contrasty negative has a long range of tones, and so must be printed upon a soft paper (long exposure scale) which is capable of recording a long range of tones.

A soft negative has a short range of tones and must be printed upon a hard paper (short exposure scale).

The worker soon becomes accustomed to estimating his negatives as soft, normal, or hard, and with a little experience in seeing the results on paper, can quite correctly estimate the kind of paper needed. A test is made by giving the paper several different, but approximately correct, exposures through the negative and seeing if any one of them records its full scale, and renders a close enough approximation to both black and white, if the negative is full scale.

EXPOSURE.— With a given paper, the length of exposure depends upon the intensity of the light, which varies with its strength and its distance from the paper. With a constant light source, the intensity varies, nearly enough for practical purposes, inversely as the square of the distance. With many papers, but not with all, a weak illumination with correspondingly long exposure results in slightly increased contrast in the print. The contrast of a print can be somewhat increased by printing through a yellow filter, or decreased by printing through a green or violet filter. The effect of an intermittent illumination is slightly less than that of a continuous illumination of the same value, and the effect of a feeble illumination is less than that of an intense illumination when timed to give theoretical exposures of equal value.

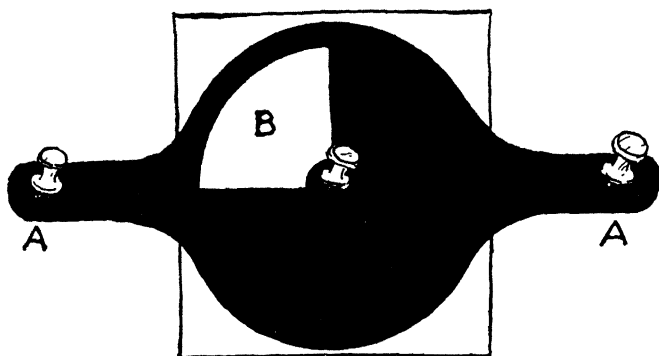
Errors in exposure can be compensated for only to a limited degree by changes in development time, and then usually only by some sacrifice of print quality.

Exposure time can be calculated by sensitometric measurements of the density range and extreme densities of the negative, and calibration of the light with the paper. This method at the same time provides a guide for the choice of paper, but it has to be done with extreme accuracy, and necessitates frequent re-calibration of the light and the paper to detect the changes that are inevitable in them.

A photoelectric integrator can be used to measure the light transmitted by the whole area of a negative and the exposure calculated by the ratio between this amount of light and that transmitted by a master negative for which the exposure is known. This method does not allow for fluctuations in the light source, for variations in the speed of the paper, nor for variations from normal in the negative as in the case of preponderant areas of unimportant tones in the picture.

By far the most common method of calculating exposure is by the use of a test strip which is given a series of exposures through the negative. The time of these exposures should progress arithmetically (3, 6, 9, 12 seconds, etc.), rather than geometrically (3, 6, 12, 24 seconds, etc.), because the paper is susceptible to very slight changes in exposure. The usual method is to expose a strip of paper by uncovering it in small steps, but in this way, when the strip is developed, comparison has to be made between dissimilar parts of the

negative. A much better way, more easily adapted to projection printing than to contact printing, is that described by Mente in *The British Journal Almanac*, 1931. This requires a circular mask of opaque paper with extending arms on two sides and with one quadrant cut out as shown at B in the illustration. The mask is pinned to the easel at points A, and so placed that a typical portion, or the most important part, of the image appears in the cut-



DEVICE FOR MAKING TRIAL EXPOSURES

out section. A test sheet is held under the mask by a thumbtack going through both mask and paper at the center. After the first exposure is made, three more exposures are made, rotating the paper a quarter turn before each. The developed print will show four printings of the same part of the subject, which can be easily compared.

Test strips, by whatever method obtained, should always be developed for the time, and at the temperature, recommended by the manufacturer of the paper.

Grease-spot photometers for measuring the intensity of the projected image are commercially obtainable and are used by multiplying their readings by a predetermined factor for the speed of the paper in use.

Edward S. King (*Brit. J. Phot.*, 1906, 53, 188) and Rev. F. C. Lambert (*Amat. Phot.*, 1921, p. 161) described certain methods in which the image thrown upon the easel is examined by the light of a candle and the distance noted at which the candle must be placed in order to obliterate all traces of the image. This distance in inches is then squared and the result multiplied by a correction factor which depends upon the aperture, the paper, etc., and is found by trial for any given set of conditions.

There are several electric exposure meters made especially for calculating the correct exposure from a projected image, but any ordinary photoelectric or extinction meter can be used by multiplying its reading by a correction factor for the speed of the paper and allowing for the color of the negative if it is other than black.

DEVELOPMENT. — The emulsion upon developing-out papers is very thin, and is intended to be developed to finality. Any development short of this will not result in the best print quality. The time of development varies with different papers and different developers. It is usually stated by the manufacturer, and should be adhered to by the worker by so timing the exposure that the print will be developed to finality in the recommended time. Shorter development will result in muddy and uneven prints because the developer has not had time to permeate the emulsion evenly. Longer development is likely to result in stain and fog, and a weaker image. Chlorobromide paper has a certain latitude in development time, with correlated exposure, by which differences in the color of the image may be produced. Chloride papers develop fastest, development usually being complete within a minute; bromide papers may take up to 3 minutes; and chlorobromide from $1\frac{1}{2}$ to 3 minutes depending upon the color wanted; but in every case the manufacturer's recommendation should be followed.

An adjustment of developing time must be made for differences of temperature, and this can conveniently be done by using the factorial system, as mentioned for negative development on page 80. As with negatives, this method requires that the exposure be approximately correct.

When paper, especially rough paper in large sizes, is placed in the developer, air bells are likely to form on its surface. These must be broken immediately or they will cause spots on the print where the developer cannot get at the emulsion. They can usually be broken by rocking the tray, but in obstinate cases must be broken by a finger, or a camel's-hair brush.

It is sometimes advisable, especially with very rough papers like Gevaluxe or Tiger-tongue, to wet the paper before applying the developer, allowing it to stay in water until it is limp, to avoid the danger of air bells, and to make sure that the developer will flow over it evenly. This previous wetting is likely to result in a somewhat softer print. It cannot be used with the factorial system of development.

The degree to which paper should be printed can be learned only by experience. Prints appear more luminous when wet than after they are dry. They appear darker under a safelight than they do under a white light. Some papers darken perceptibly when placed in the short-stop or hypo, and some are slightly bleached in the hypo, especially if they are allowed to stay in it very long. All papers darken, through losing some of their reflective power, when they dry, and this loss is greater with some papers than with others. All these factors must be allowed for when judging the tone of the print under the darkroom light, and how much to allow can be learned only by experience. With an unknown paper, it is the part of wisdom to make a trial print and after development and fixation, observe its appearance carefully under the darkroom light. Then rinse it briefly, remove the surface water with a sponge or blotting paper and dry with heat, so that its depth of tone can be quickly

compared with its remembered appearance under the darkroom light, or with a duplicate print which has been left in the wash water.

The developer should be constantly agitated in two directions during development, to avoid streaks and uneven markings. This can be done by rocking the tray, which should be done alternately in two directions. Prints should be examined as they lie in the tray, under the developer, and not taken out for examination, as exposure to air while there is developer in the emulsion is likely to cause fog, to which some papers are more susceptible than others. Degradation by fog so slight as to escape identification as such may detract much from the appearance of a print.

MANIPULATION DURING DEVELOPMENT. — Quite considerable control can be exercised during development. Contrast can be reduced and shadow detail brought out by transferring the paper during development to a tray of water, where detail will continue to build up. The paper can be returned to the developer and the process repeated. Local parts can be held back by swabbing them with glycerin, or the print can be placed in a tray of water and local parts forced by applying developer to them with a tuft of cotton or a brush. Areas can be darkened by receiving a flat exposure during development from a flashlight whose lens has been covered by black paper with a small hole in it through which the light is played.

Papers vary greatly in the degree to which they can be manipulated without incurring fog and stains which are always likely to occur when anything except straight development is attempted.

DEVELOPERS. — While practically any developing agent that can be used for negatives will develop papers, many of them are not suitable because of their proclivity to stain, and because they give a colored image. In practice, the developers most commonly used are amidol, paraminophenol, and various combinations of metol and hydroquinone.

For chloride papers the concentration of sodium sulphite has to be kept to a minimum, or yellow stain will result, on account of the rapidity with which silver chloride dissolves when as finely divided as in emulsions used on paper.

For best results the formula recommended by the manufacturer should be used, as it has been designed to get the utmost quality out of the paper. However, the maker's formulas for the same kind of paper are very similar, and they can often be interchanged if the worker is sure of the similarity of the papers, or if trial has proved that it is satisfactory.

With metol-hydroquinone developers, softer effects can be secured by decreasing the proportion of hydroquinone and sodium carbonate to the metol; and more contrasty effects by increasing them. The special formulas supplied by the makers are best for these effects, although such changes are often successfully made experimentally by the worker. There is danger of stain unless the sodium sulphite is kept proportionate to the total amount of reducing agents.

DEVELOPERS FOR CHLORIDE PAPERS.—The following table presents some of the formulas that are most used for chloride papers, and affords a convenient method of comparing them. The quantities are in grains.

DEVELOPERS FOR CHLORIDE PAPERS

	<i>Metol</i>	<i>Hydroquinone</i>	<i>Sodium sulphite</i>	<i>Sodium carbonate</i>	<i>Potassium bromide</i>	<i>Potassium sulphocyanate (Thiocyanate)</i>	<i>Water</i>
Agfa Convira (N-103).....	8.5	27.5	137	192.5	3	—	16 oz.
Cykon (135).....	6	24	95	95	10	—	16 oz.
Defender Apex, No. 1.....	7.5	30	110	165	4.5	—	16 oz.
Apex, No. 2.....	7	26	96	182	2	—	16 oz.
Apex, No. 3.....	7.5	30	110	110	10 to 20	—	16 oz.
Artura Iris.....	5.5	22.5	82.5	55	1.5	—	16 oz.
Eastman							
Azo, commercial (D-73)	6.5	26	96	185	2	—	16 oz.
Azo, portrait (D-52)...	5.5	22.5	82.5	55	1.5	—	16 oz.
Velox (D-72).....	7.5	30	120	180	5	—	16 oz.
Vitava (D-52).....	5.5	22.5	82.5	55	1.5	—	16 oz.
Gevaert Novagas (G251)....	10	45	180	360	7.5	—	16 oz.
G252	22.5	45	180	360	3.5	—	16 oz.
Haloid Nomis.....	7.5	30	120	192	5	1.5	16 oz.

The Eastman D-72 formula comes so near to the average of other makers' formulas that it is often used universally.

ELON-HYDROQUINONE UNIVERSAL PAPER DEVELOPER (Eastman D-72)

Stock Solution

Water (about 125° F.) (52° C.)	16 oz.	500 cc
Elon	45 gr.	3.1 g
Sodium sulphite	1½ oz.	45 g
Hydroquinone	175 gr.	12 g
Sodium carbonate	2½ oz.	67.5 g
Potassium bromide	27 gr.	1.9 g
Water to make	32 oz.	1000 cc

For chloride papers, take 1 part stock solution, 2 parts water. Develop about 45 seconds at 70° F.

For bromide papers, take 1 part stock solution, 4 parts water, and develop not less than 1½ minutes at 70° F.

For colder, blue-black tones, the developer is somewhat modified, and less bromide is used.

By varying the proportions of the developer and using different amounts of bromide, with compensating times of exposure and development, metol-hydroquinone can be made to yield a variety of tones ranging from a cold

blue-black to warmer black or brown with an olive tinge, which are useful for special effects. The following formulas are typical.

ELON-HYDROQUINONE (Eastman D-73)
(For blue-black tones)

Stock Solution

Water (about 125° F.) (52° C.)	16 oz.	500 cc
Elon	40 gr.	2.8 g
Sodium sulphite	1 oz., 140 gr.	40 g
Hydroquinone	155 gr.	10.8 g
Sodium carbonate	2½ oz.	75 g
Potassium bromide	12 gr.	0.8 g
Water to make	32 oz.	1000 cc

For use take stock solution 1 part, water 2 parts. Develop for 45 seconds at 70° F. (21° C.).

METOL-HYDROQUINONE (Agfa 103)
(For cold, blue-black tones)

Stock Solution

Water (about 125° F.) (52° C.)	24 oz.	750 cc
Metol	50 gr.	3.5 g
Sodium sulphite	1½ oz., 50 gr.	57 g
Hydroquinone	¼ oz., 55 gr.	11.5 g
Sodium carbonate (monohydrated)	2½ oz., 35 gr.	78 g
Potassium bromide	18 gr.	1.2 g
Water to make	32 oz.	1000 cc

For use dilute 1 part stock solution with 2 parts water. Normal development time, 1 minute at 70° F. (21° C.).

For warm black tones the exposure is lengthened and a weaker developer with more bromide is used.

DEVELOPER FOR WARM, BLACK TONES (Agfa 135)

Water (about 125° F.) (52° C.)	24 oz.	750 cc
Metol	24 gr.	1.6 g
Sodium sulphite	¾ oz., 20 gr.	24 g
Hydroquinone	96 gr.	6.6 g
Sodium carbonate (monohydrated)	¾ oz., 20 gr.	24 g
Potassium bromide	40 gr.	2.8 g
Water to make	32 oz.	1000 cc

For use dilute 1 part stock solution with 1 part water. Normal development time 1½ to 2 minutes at 70° F. (21° C.).

DEVELOPER FOR WARM, OLIVE-BLACK TONES (Agfa 106)

Water (about 125° F.) (52° C.)	24 oz.	750 cc
Metol	10.5 gr.	0.7 g
Sodium sulphite	¼ oz., 60 gr.	11.5 g
Hydroquinone	50 gr.	3.5 g
Sodium carbonate (monohydrated)	½ oz., 35 gr.	10 g
Potassium bromide	35 gr.	2.4 g
Water to make	32 oz.	1000 cc

Do not dilute for use. Normal development time, 1 minute at 70° F. (21° C.).

Amidol is very suitable for developing any kind of developing-out papers if a blue-black tone is desirable. It is much used by people who are susceptible to metol poisoning. Less bromide is used for chloride papers than for bromide papers.

AMIDOL DEVELOPER FOR CHLORIDE PAPERS

Sodium sulphite	$\frac{1}{2}$ oz.	32 g
Potassium bromide	1 gr.	0.13 g
Water	16 oz.	1000 cc
When dissolved, add:		
Amidol	40 gr.	5.2 g

This does not keep well in solution and should be freshly mixed before use.

To avoid the use of scales, amidol is frequently measured instead of weighed, allowing 1 teaspoonful of amidol for 50 grains and 1 teaspoonful of sodium sulphite for 100 grains. Potassium bromide can be purchased in drug stores in 5-grain tablets. Because amidol developers contain no carbonate, they are the only developers which do not require more exact compounding. Any slight difference in the amount of amidol means only a corresponding difference in time of development. For the above formula it would be quite sufficient to take 1 teaspoonful of amidol, 2 of sulphite, 1 grain of bromide, and 16 ounces of water. Amidol is not as sensitive to the action of bromide as some other developers are, and the above amount is a minimum, which may be increased if needed.

Glossy papers sometimes show fine, hair-like lines that are caused by abrasion on the sensitive surface. The following developer has been suggested as a means of obviating these:

NON-ABRASION DEVELOPER

Metol	27 gr.	3.5 g
Hydroquinone	46 gr.	6 g
Sodium sulphite	92 gr.	12 g
Sodium carbonate	154 gr.	20 g
Potassium bromide	3 gr.	0.4 g
Potassium iodide	15.4 gr.	2 g
Water	16 oz.	1000 cc

The iodide which is the active agent in preventing abrasion marks may be added to any suitable developer in about the above proportions; 1 grain per ounce or 2 grams per liter. When this developer is used, the undeveloped parts of the prints will turn yellow (due to the silver iodide that is formed) and the disappearance of this yellow stain in the fixing bath is a visible sign of complete fixation.

Another way to prevent abrasion marks is to add 0.156 per cent of hypo to the developer, that is, 1.56 grams per liter or 12 grains per 16 ounces.

As these abrasion marks are on the surface of the emulsion, they may usually be removed by rubbing with alcohol on a wad of cotton.

Paraminophenol is usually used in proprietary form (Rodinal, etc.). It has the advantage of keeping indefinitely in stock solution, and exceptionally well when diluted for use. The tone of the prints can be quite materially changed by differences of dilution, and by adding bromide.

Warm tones can be secured by pyro, although not so conveniently as by the modified metol-hydroquinone developers which have generally superseded it for this purpose.

WARM TONE PYRO DEVELOPER FOR PAPER

Solution A

Potassium metabisulphite	38.5 gr.	5 g
Pyro	169 gr.	22 g
Potassium bromide	115 gr.	15 g
Water	16 oz.	1000 cc

Solution B

Sodium sulphite	672 gr.	87.5 g
Sodium carbonate	672 gr.	87.5 g
Water	16 oz.	1000 cc

For use mix 10 parts solution A and 20 parts solution B with 70 parts of water.

The image appears in from 30 to 40 seconds and development is complete in 3 or 4 minutes. The prints should then be fixed in an acid fixing bath without intermediate washing.

The following table gives in a form convenient for comparison some of the more commonly used manufacturers' formulas for bromide paper. The parts are in grains, unless otherwise specified.

DEVELOPERS FOR BROMIDE PAPERS

	<i>Metol</i>	<i>Hydro-quinone</i>	<i>Sodium sulphite</i>	<i>Sodium carbonate</i>	<i>Glycin</i>	<i>Potassium bromide</i>	<i>Water</i>
Brovia 125	4.5	18	66	100		3	16 oz.
115	—	17.5	165	275	55	7.5	16 oz.
Indiatone	7	35	100	88		7	16 oz.
135	6	24	88	88		10	16 oz.
Dassonville	11.5	41	137.5	110		15	16 oz.
Defender Velour Black	6	24	88	88		10-25	16 oz.
Veltura	5.5	22.5	82.5	55		2.5	16 oz.
Eastman (D-52) for Portrait Bromide and Translite	11	45	165	110		5	16 oz.
(D-72) for P.M.C.	4.5	17.5	66	99		2.7	—
Gevaert G251	10	45	180	360		7.5	16 oz.
G252	22.5	45	180	360		3.5	16 oz.
G253	22.5	7.5	145	180		7.5	16 oz.
G261		45	315	278	45	15	16 oz.
G262		420	550	720		15	16 oz.
Haloid		24	88	88		3	16 oz.

The Eastman D-64 formula, originally intended for Vitava Athena and Opal, is largely used for many kinds of chlorobromide papers, on account of the ease with which different degrees of contrast can be secured.

TWO-SOLUTION ELON-HYDROQUINONE DEVELOPER (Eastman D-64)

Stock Solution A

Water (about 125° F.)	16 oz.	500 cc
Elon (metol)	68 gr.	4.7 g
Sodium sulphite	1 oz., 55 gr.	33.8 g
Hydroquinone	75 gr.	5.2 g
Sodium carbonate	385 gr.	26.9 g
Potassium bromide	35 gr.	2.4 g
Cold water to make	32 oz.	1000 cc

Stock Solution B

Warm water, as above	16 oz.	500 cc
Sodium sulphite	1 oz., 55 gr.	33.8 g
Hydroquinone	275 gr.	19.2 g
Sodium carbonate	285 gr.	26.9 g
Potassium bromide	35 gr.	2.4 g
Cold water to make	32 oz.	1000 cc

For soft prints from contrasty negatives take:

Stock solution A	12 oz.	360 cc
Water	20 oz.	600 cc

For medium prints from average negatives, take:

Stock solution A	6 oz.	180 cc
Stock solution B	6 oz.	180 cc
Water	20 oz.	600 cc

For hard prints from soft or flat negatives, take:

Stock solution A	6 oz.	180 cc
Stock solution B	12 oz.	360 cc
Water	14 oz.	420 cc

and to each 32 ounces (1000 cc) of developer ready to use, add 1 dram (4 cc) of 10 per cent potassium bromide solution. Use the developer at a temperature of 70° F. (21° C.). More bromide may be added if warmer tones are desired.

The Eastman D-52 formula is typical of the developers used for chlorobromide papers.

ELON-HYDROQUINONE DEVELOPER (Eastman D-52)

Stock Solution

Water (about 125° F.) (52° C.)	16 oz.	500 cc
Elon	22 gr.	1.5 g
Sodium sulphite	$\frac{3}{4}$ oz.	22.5 g
Hydroquinone	90 gr.	6.3 g
Sodium carbonate	$\frac{1}{2}$ oz.	15 g
Potassium bromide	22 gr.	1.5 g
Cold water to make	32 oz.	1000 cc

For use develop not less than 1½ minutes at 70° F. (21° C.). This developer contains the minimum quantity of bromide. More bromide may be added if warmer tones are desired.

Dr. Roland F. Beers in the AMERICAN ANNUAL OF PHOTOGRAPHY 1940 gives directions for stock solutions of a developer which may be combined in different proportions so that it will give a progressive range of contrasts.

Solution A

Metol	120 gr.	8 g
Sodium sulphite	350 gr.	23 g
Potassium carbonate	300 gr.	20 g
Potassium bromide	16 gr.	1.1 g
Water to make	32 oz.	1000 cc

Solution B

Hydroquinone	120 gr.	8 g
Sodium sulphite	350 gr.	23 g
Potassium carbonate	400 gr.	27 g
Potassium bromide	32 gr.	2.2 g
Water to make	32 oz.	1000 cc

<i>Solution No.</i>	<i>Extreme low contrast</i>		<i>Normal contrast</i>				<i>Extreme high contrast</i>
	1	2	3	4	5	6	7
A.....	8	7	6	5	4	3	2
B.....	0	1	2	3	4	5	14
Water.....	8	8	8	8	8	8	0
Total ounces. . . .	16	16	16	16	16	16	16

Amidol is the favorite of many people for developing bromide paper, especially for soft and high-key prints which are obtained by suitably diluting the standard developer. This developer is preferred by many who are susceptible to metol poisoning. The developer should be mixed fresh each time before use.

AMIDOL DEVELOPER (Agfa 113)

Amidol	96 gr.	6.6 g
Sodium sulphite	1½ oz., 90 gr.	44 g
Potassium bromide	8 gr.	.55 g
Water to make	32 oz.	1000 cc

Do not dilute for use. Normal development time, 1 to 2 minutes at 70° F. (21° C.).

The following table shows the great difference in various manufacturers' formulas for the use of amidol. These discrepancies affect only the time of development, and the keeping qualities of the solution.

BROMIDE PAPER AMIDOL DEVELOPERS

	<i>Amidol</i>	<i>Sodium sulphite</i>	<i>Potassium bromide</i>	<i>Water</i>
Dassonville	40	120	4	16 oz.
Eastman D-51	55	176	—	16 oz.
Gevaert	40	520	6	16 oz.

Glycin is often used for bromide papers on account of the pleasing, pure black tones that it produces, even on papers that usually give greenish tones.

GLYCIN DEVELOPER

Water	32 oz.	1000 cc
Sodium sulphite	3½ oz.	100 g
Trisodium phosphate (monohydrated) ...	4½ oz.	125 g
Glycin	375 gr.	25 g
Potassium bromide	45 gr.	3 g

Dilute with 3 parts of water for chloride and chlorobromide papers, and with 4 parts of water for bromide papers. Development is usually complete in 2 or 3 minutes, but in case of underexposure it can be prolonged without ill effects.

Another glycin formula gives brown or sepia tones on chloride or chlorobromide papers, and black upon bromides.

WARM TONED GLYCIN DEVELOPER (Edwal 106)

Water	35 oz.	1000 cc
Sodium sulphite	3 oz.	85 g
Sodium carbonate	5 oz.	145 g
Glycin	1 oz.	28 g
Hydroquinone	135 gr.	9 g
Potassium bromide	62 gr.	4 g

Dilute with 7 parts of water. For special effects on chloride papers, expose three times normal and stop development when effect is secured. With three times normal exposure and the stock developer diluted with 15 parts of water, "gravure-brown" tones are secured on the fast chlorobromide papers.

Adurol, or Chlorhydroquinone, are trade names for the monochlor or monobrom derivatives of hydroquinone. It is so much more energetic than hydroquinone (see page 69) that it can be used without caustic alkalis, and it also works at lower temperatures. It is less sensitive to bromides than hydroquinone. As it has little tendency to produce fog, it is a very desirable developer for papers, giving warm black, brown, or sepia tones by direct development. It is often substituted for hydroquinone in any formula that also contains metol, in the ratio of 1.3 parts of chlorhydroquinone for 1 part of hydroquinone.

CHLORHYDROQUINONE DEVELOPER

Sodium sulphite	220 gr.	14 g
Sodium carbonate	175 gr.	11 g
Potassium bromide	16 gr.	1 g
Chlorhydroquinone (or Adurol)	60 gr.	4 g
Water to make	20 oz.	600 cc

This gives a warm black. Other tones are easily secured by increasing the exposure and diluting the developer and adding more bromide. The effect

varies with different papers and is best learned by trial. Fix in 20 per cent hypo, acidified with $2\frac{1}{2}$ per cent potassium metabisulphite.

Metol-chlorhydroquinone is often used instead of metol-hydroquinone because its effect is less modified by changes in temperature, its activity remaining at temperatures so low that hydroquinone would be inert.

METOL-CHLORHYDROQUINONE

Metol	16 gr.	1.8 g
Chlorhydroquinone	48 gr.	5.5 g
Sodium sulphite	220 gr.	25 g
Sodium carbonate	175 gr.	20 g
Potassium bromide	4 gr.	0.4 g
Water to make	20 oz.	1000 cc

Warm tones can also be obtained by using the ferrous oxalate developer (page 90) suitably diluted, but it is liable to cause stains, and has been generally superseded by chlorhydroquinone and glycin.

SHORT-STOP. — Rinsing of prints in an acid bath for at least 5 seconds between developing and fixing is to be strongly recommended because it checks development instantly, affording close control of the action of development, and prevents stains. It also prevents neutralization of the acidity of the fixing bath by the alkaline developer that would otherwise be carried over into it, thus prolonging the life of the fixing bath.

ACID SHORT-STOP

Water	32 oz.	1000 cc
Acetic acid (28 per cent)	$1\frac{1}{2}$ oz.	50 cc

Keep the prints separated and moving while in this bath. If the prints have previously been well drained of developer, about 1500 square inches of paper can be processed in this bath before it loses its acidity, but it is good practice to use a fresh bath for each batch of prints.

FIXING. — Prints fix much more rapidly than negatives on account of the thinness of the emulsion, the lower concentration of silver halides, and the finer grain. In a *fresh* fixing bath the time is seldom over 1 or 2 minutes, and this fact can be utilized when speed is essential, but it must be remembered that the bath is no longer fresh after even one print is fixed in it. The recommended time of 10 or 15 minutes in a bath in which several prints are fixed, gives a margin of safety which is often no more than necessary.

The fine-grained image on paper is slightly soluble in hypo, and more so in acid hypo. If prints are left in it longer than the recommended time, there will be a reduction in the depth of both highlights and shadows. In an absolutely fresh bath the time may not be longer than 5 minutes before reduction starts.

If absolute permanency is desired, prints should be fixed in two successive baths. The first bath retains all the accumulations from the developer, and

is also constantly diluted by the water that is carried over into it from the rinse, so that the strength of its action can never be absolutely known. After 4 or 5 minutes in the first bath and a slight rinse, the print is placed for 2 or 3 minutes in a fresh bath which acts upon it with full strength.

Prints should be moved about when first placed in the hypo, so that the action will begin simultaneously all over the print. They should be fixed face up, so that it can be seen that the hypo has constant access to every part of the print. If the concentration of hypo is too great, some papers will float on the surface and parts of them will protrude and be reduced by the oxygen in the air, and other irregularities may occur. The concentration of hypo should be reduced so that the prints will sink beneath its surface. A 20 per cent solution of hypo is usually satisfactory. If prints are fixed face down, air bells are likely to be trapped under them, preventing access of the hypo to the print.

A plain solution of hypo will fix prints, but it soon becomes contaminated by the developer carried over into it unless this is neutralized by an acid, for which potassium metabisulphite is commonly used. Sodium bisulphite is cheaper, and its action is so similar that it may be substituted weight for weight in all formulas.

FIXING BATH FOR PAPERS

Hypo	4 oz.	200 g
Potassium metabisulphite	175 gr.	20 g
Water	20 oz.	1000 cc

As with negatives, an acid-alum fixing bath is generally used because it retains its useful life longer, and prevents blister and frilling. Chrome alum can be used with some papers, but with others it causes a stain. It should not be used until a test has been made by fixing two strips of the unexposed paper, one in plain hypo and the other in the hypo-chrome alum bath, to see if stain results.

ACID-HARDENING FIXING BATH FOR PAPERS (Eastman F-1)

Sodium thiosulphate (Hypo)	8 oz.	240 g
Water to make	32 oz.	1000 cc

When dissolved completely, add all of the following hardening solution:

Water (about 125° F.) (52° C.)	2½ oz.	80 cc
Sodium sulphite	½ oz.	15 g
Acetic acid (28 per cent)	1½ oz.	48 cc
Potassium alum	½ oz.	15 g

The sodium sulphite should be dissolved completely before adding the acetic acid. After the sulphite-acid solution has been mixed thoroughly, add the potassium alum with constant stirring. When dissolved, make up the final volume with cold water.

This bath will fix approximately sixty 8 by 10 inch prints per gallon or their equivalent in other sizes, if a water rinse is used after development; or double that amount of paper if an acid rinse bath is used. The temperature of this fixing bath should be kept as near 70° F. as possible.

ACID-HARDENER STOCK SOLUTION (Eastman F-1a)

Water (about 125° F.) (52° C.)	56 oz.	1700 cc
Sodium sulphite	8 oz.	240 g
Acetic acid (28 per cent)	24 oz.	750 cc
Potassium alum	8 oz.	240 g
Cold water to make	128 oz.	4000 cc

Mix according to instructions for formula F-1 above. A fixing bath is made quickly by adding 1 part of this hardener to 4 parts of 25 per cent cool hypo solution.

WASHING. — The elimination of hypo proceeds much more slowly from paper than from plates and film. The fibers of the paper and the baryta coating retain the hypo tenaciously, and the law of constant fractional reduction by which hypo is washed out of film does not apply to paper. As the quantity becomes smaller, the rate of elimination is decreased. Rapid renewal of the water cannot speed the process up as it is dependent upon the time of diffusion of the salts from the support. A certain amount of soaking is necessary, although this should be in fresh water all the time. If the prints collect in batches, diffusion will be hindered, or stopped altogether. Hickman has demonstrated that even under the most favorable conditions thin papers must be washed for at least one-half hour and thick papers from 1 to 1½ hours.

There are many efficient washing machines on the market which are useful in commercial establishments, but they are too bulky or too expensive for the average amateur. A good arrangement is to wash in a large tray with a siphon that supplies a constant stream of fresh water and draws off the hypo-laden water from the bottom of the tray. Bathtubs and laundry tubs can be used effectively. They should be filled with water so that the prints float vertically, suspended from split corks held together by rubber bands, with a rustless clip attached to the bottom, if necessary. The water should be conducted to one end of the tub by a hose from the faucet, and allowed to escape through a perforated plug in the outlet at the bottom. Whatever the method of washing, it should receive frequent attention to see that the prints do not bunch together.

The flow of water should be regulated so that the water is completely replaced ten or twelve times an hour. This may be determined by adding to the water enough 10 per cent solution of potassium permanganate to color it appreciably, and then noting the time that it takes the color to disappear. The flow of water can then be adjusted so that the receptacle empties ten or twelve times an hour.

The tests for the elimination of hypo mentioned on page 107 in connection with washing negatives, may be applied to prints, to ascertain when they are free from hypo. Once the approximate time has been learned for papers of different thicknesses, it can be used, with a slight margin of safety, for future operations under identical conditions, without further tests. A rough test, if acid hypo has been used, is to taste the print.

Unlike negatives, prints wash faster in warm water than in cold. If the temperature of the wash water is below 65° F., the time should be increased. If the water is over 100° F., the gelatin is likely to be softened, and blisters may appear. Washing may be speeded up by placing the prints, after fixation, in a 1 per cent solution of sodium carbonate for 1 minute. A higher concentration, or longer time, may discolor the paper.

Tap water in the summer sometimes contains decayed vegetable matter which stains prints yellow during prolonged washing. Such water can usually be decolorized by passing it through a filter containing activated charcoal.

DRYING.—The surface water may be removed from mat or semi-mat prints by pressing them between blotting paper, or by wiping them with a chamois, viscose sponge, or a linen cloth. If blotters are used, they should be of the kind specially prepared for photographic use, as ordinary blotters contain substances that would stain the prints. Drying is completed by placing the prints face down on dry blotting paper, or upon stretchers covered with cheesecloth or galvanized wire netting, or by suspending them in the air. Just before they are completely dry, the prints are placed between dry blotters under pressure. If allowed to become bone-dry on the stretchers, they will curl badly and can be straightened only by dampening the backs and placing under pressure. If wet prints are allowed to dry between blotters, they will stick to the blotters. The blotter-roll is a convenient device in which the prints are laid face down on a cloth-surfaced blotter, covered with a plain blotter, and then rolled with the emulsion side out in corrugated cardboard. The roll can be placed in a current of warm air which the corrugated board gives access to the prints. The prints come out with a slight backward roll, and after exposure to the air, lie perfectly flat.

Drying may be hastened by soaking the washed print in methyl alcohol until it becomes transparent, and then drying by heat, or by burning the alcohol off. Rapid drying by any method is not advocated unless necessary, as it usually impairs the color and brilliancy of the print.

Glossy prints are dried upon black, enameled ferrotype plates, or upon chromium plates which are more expensive but perhaps cheaper in the long run as they scratch less easily, are more durable, and are less liable to cause the plates to stick. Plate glass polished with rouge, or sheets of celluloid are sometimes used instead of the metal plates, but they do not give as glossy a finish. Any scratches on the plates will be reproduced on the glossy surface of the print. Plates should be washed after using, with warm water and a

mild soap sparingly applied. The plates are polished just before use with a commercial preparation made for the purpose, or with a sludge made by dissolving 10 grains of paraffin in 1 ounce of benzene. Apply this thoroughly to the whole surface of the plate, then polish with a soft cloth until no trace of it remains. The washed prints are placed, without draining, face down on the plates, bending the paper backwards and first applying one corner which may be held in place with the thumb while the rest of the print is laid down in a quick, continuous motion to avoid air bells. An alternative way is to bring plate and paper into contact under water. The paper is then covered with a blotter and squeegeed on to the plate by a flat or roller squeegee to drive out all the water under the print and leave it in perfect contact. If the previous processes have been long, especially in hot weather, the gelatin may be so soft that it would stick to the plate, in which case the print is first dried and then wet again before applying it to the plate. The plates are set in a current of air, which may be quite warm, until the prints drop off of their own accord. If force is used to remove the prints from the plates they will surely be injured.

Prints were formerly dipped in a solution of ox-gall before applying them to the plate, to give them a greater gloss, but this evil-smelling solution has fallen into disuse. If the plate is well polished, the print will equal it in gloss. Subsequent dampening will remove the gloss.

INTENSIFICATION AND REDUCTION. — Prints may be intensified or reduced by the same agents that are used for negatives, using more diluted solutions to keep the work under control (see pages 120 to 136). Dull, overexposed, or overdeveloped prints, after being fixed, are noticeably brightened by a dip in Farmer's reducer, followed by washing. After any intensification or reduction treatment, plunge the print immediately into running water to stop the action without waiting to see if it is sufficient. It easily gets out of hand, and it can be repeated if necessary. Mercury intensification is unsatisfactory with papers as it reduces the transparency of the shadows, causes graininess, and impairs the permanence of the prints. Chromium intensification is entirely satisfactory. Persulphate, and permanganate reducers may be used. Iodine-cyanide is particularly suitable for print reduction because it leaves no residual stain, as some other reducers are likely to do even after prolonged washing.

IODINE-CYANIDE PRINT REDUCER

Working Solution

Sodium or potassium cyanide	73 gr.	5 g
Iodine stock solution	1½ oz.	49 cc
Water to make	32 oz.	1000 cc

IODINE STOCK SOLUTION

Water	5 oz.	160 cc
Potassium iodide	110 gr.	8 g
Iodine crystals	110 gr.	8 g

The iodine stock solution will keep for several months, but the mixed solution should be used as soon as possible after mixing.

Note that the cyanide is a deadly poison which should be handled only with rubber gloves and in a room with good ventilation. Wash the hands thoroughly after handling it. Do not pour this solution into a sink containing acid, or the very poisonous hydrogen cyanide gas will be formed. Flush the sink quickly with water after discarding the solution.

Iodine-cyanide is especially suitable for local reduction of prints because it does not change the color of the image.

Dry prints can be locally reduced with iodine and thiocarbamide in methyl alcohol. This method is advantageous because the reducer can be kept closely confined to the portion of the print where it is wanted.

IODINE-THIOCARBAMIDE REDUCER

<i>Solution A</i>		
Iodine	40 gr.	2 g
Methyl alcohol	2 oz.	46 cc
Shake occasionally until dissolved.		

<i>Solution B</i>		
Thiocarbamide	80 gr.	4 g
Water to make	2 oz.	46 cc

For use, take equal parts of solution A and solution B, diluting with water if only slight reduction is desired. Apply to local area with a small brush and immediately swab with methyl alcohol in a tuft of cotton. Blot off excess of alcohol, and repeat the process until the desired amount of reduction is secured. Fix in hypo, and wash.

STERRY PROCESS.—When the scale of a negative is too long to be printed upon a given paper, it can be compressed by using the Sterry process.

STERRY PROCESS

<i>Stock Solution</i>		
Potassium bichromate	50 gr.	3.7 g
Ammonia	5 minims	1 g
Water	1 oz.	85 cc

The working solution is made by taking 10 ounces of water and adding to it from 20 to 50 minims of the stock solution for chloride papers, 50 to 100 minims for bromide, or an intermediate amount for chlorobromide papers. The amount to be used varies with the amount of control wanted, and has to be learned by experience for each paper used, but judgment is soon acquired, and the process is a very convenient one in an emergency, and much used. The paper is printed for highlight detail, regardless of how much it overexposes the shadows. The print is immersed in the restraining solution for 2 or 3 minutes, rinsed in running water for about a minute to discharge the yellow bichromate stain, and then developed as usual. If the solution is too strong, or applied for too long a time, the color of the print will be poor.

DIRECT POSITIVE PAPER. — This paper is used for making negatives which, by the six operations of the reversal process, are changed into positive prints. Correct exposure for the negative determines the quality of the print; therefore a fixed light source and a definite exposure are required. Underexposure will produce a dark picture, while overexposure produces pictures which are too light.

The reversal process includes exposure, development of the negative, bleaching the negative, clearing, re-exposure, development of the positive. Fixing is not essential, but it gives the print a slightly increased brilliance. Fixed prints should be washed for 10 minutes in running water. If not fixed, prints should be washed for 4 or 5 minutes. The Direct Positive emulsion is coated on a waterproof support which permits rapid drying. An inexpensive electric hair dryer can be used effectively to facilitate drying. The Series 2 Wratten safelight should be used for workroom illumination.

A satisfactory division of time in the different solutions is as follows: developing, 45 seconds to 1 minute; bleaching, 30 seconds; clearing, 30 seconds; developing or redeveloping, 30 seconds; fixing, 30 seconds. It is necessary to wash the prints thoroughly in running water for at least 15 seconds between the different solutions. When the solution D-88 is used for developing a black-and-white positive, it is necessary to expose the paper to artificial light directly after clearing. If convenient, the white light may be turned on as soon as the prints are placed in the clearing bath. If brown tones are desired, the sulphide redeveloper may be used, instead of developer D-88, directly after clearing. It will then be unnecessary to use white light.

DEVELOPER (Eastman D-88)

Water (about 125° F.) (52° C.)	96 oz.	3000 cc
Sodium sulphite	6½ oz.	195 g
Hydroquinone	3½ oz.	97.5 g
Boric acid (crystals)	¼ oz.	22.5 g
Potassium bromide	150 gr.	10.5 g
Sodium hydroxide (caustic soda)	3½ oz.	97.5 g
Water to make	128 oz.	4000 cc

The caustic soda should be dissolved in a small volume of water, in a separate container, and added to the solution which has been made by dissolving the chemicals in the order given. Water should then be added to make 1 gallon (4000 cc). When dissolving the caustic soda, stir constantly so that the heat generated will not cause the solution to boil with explosive violence and spatter the hot caustic on the hands and face, which would produce serious burns. Use the developer full strength at a temperature of 70° F. (21° C.).

BLEACHING SOLUTION (Eastman R-9)

Solution A

Water	128 oz.	4000 cc
Potassium bichromate	1½ oz.	37.5 g
Sulphuric acid, C.P.	1½ fluid oz.	48 cc

Use full strength at 65° to 70° F. (18° to 20° C.). For more rapid bleaching, the amounts of acid and bichromate may be increased.

CLEARING SOLUTION

<i>Solution B</i>			
Sodium sulphite	12 oz.	360	g
Water	128 oz.	4000	cc

Use full strength at 65° to 70° F. (18° to 21° C.).

REDEVELOPER (Eastman D-88)

Use same as for first development, full strength at a temperature of from 65° to 70° F. (18° to 21° C.). If sepia tones are desired, use the following redeveloper directly after clearing:

SULPHIDE REDEVELOPER (Eastman T-19)

Sodium sulphide (not sulphite)	300 gr.	20	g
Water	32 oz.	1000	cc

FIXING BATH (Eastman F-1)

This formula will be found on page 165. Fixing is not essential to this process but will add somewhat greater brilliance to the black-and-white print. *It is important to wash for at least 10 minutes* to insure removal of the fixing bath from the print. If the sulphide bath (Formula T-19) has been used, fixation is unnecessary.

All chemical solutions reach a point of exhaustion beyond which they should not be used. In addition to exhaustion, a developer becomes oxidized with long exposure to air, causing yellow stains in highlights. Use fresh developer as needed and discard as soon as its action becomes slow, or any staining in the highlights is noticeable.

Bleaching should require about 30 seconds. Use a fresh solution when bleacher acts slowly, indicating exhaustion.

Insufficient clearing, or lack of washing after first development and bleaching, will cause yellow stains and streaks. Always use a reasonably fresh clearing solution.

In addition to rinsing between solutions, do not allow one chemical solution to contaminate another. Always use the same trays for the same solutions and wash them thoroughly after use.

CONTROL IN FINISHING.—The finished print usually requires a certain amount of hand work to remove blemishes even if no alterations are made. Black specks caused by pinholes in the negative, are best removed by a finely pointed knife or etching tool. A light touch will remove some or all of the silver without breaking the emulsion, which would show as a defect on the print. Light spots are darkened with pencil, crayon, or water color. Water color stippled on with a very fine brush can be made, by mixing colors, to match any tone on a print. The surface of glossy or semi-mat papers can be matched by using a trace of mucilage in the water for mixing the pigment. When applying pigment the brush should be so dry that it barely leaves a mark, which dries instantly. A watery solution leaves a hard edge. Larger areas are filled in with "crayon sauce" which may be purchased at art stores, and

rubbed on with an artist's paper or chamois stump, or with a pledget of cotton. Pencil and crayon work often show a sheen different from that of the paper. This defect can be remedied by passing the print through the steam from water boiling in a kettle. The gelatin softens enough to let the pigment sink into it, and when dry it will be imperceptible. The whole print must be treated with the steam or there will be a variation in the surface of different parts of the print. This treatment alters a mat surface, leaving it semi-mat.

For more extensive alterations, the print may be waxed and pigment applied locally with a bromoil brush. Or, the whole print may be covered with a dope of equal parts mastic varnish and linseed oil thinned with an equal amount of turpentine, to which pigment has been added. The pigment should match the color of the print, and the amount used depends upon the darkness of the print and the effect desired. This dope is rubbed uniformly all over the print and then wiped off locally with a clean cloth or a tuft of cotton to give various effects. A skilled operator can work clouds into landscapes very cleverly by this method. This is the process popularized under the name of *Mediobrome* by Léonard Misonne. Control is greatest if the print is made light, so that a good volume of pigment can be applied over-all, and lightened locally.

CHAPTER XI

TONING

The images upon developing-out papers may be toned to a variety of colors which often have a suggestive value, as green for foliage, blue for snow, etc., or the colors may be used arbitrarily for decorative processes or to get away from the hard reality of black and white. Brown and sepia tones have long been popular for portraits and other effects, and from the color of the early printing-out papers these have been considered natural photographic colors.

SULPHUR TONING.—By far the greater number of brown prints are produced by some of the sulphur toning processes. The finer the grain size of the developed image, the warmer will be the tone. The particular developer that is used makes little difference in the color of the toned print. Chloride and chlorobromide emulsions produce warmer tones than silver bromide. Development in solutions heavily restrained with bromide give finer grain, and hence produce warmer tones. Short development produces warmer tones than long development. The images formed by sulphur toning are absolutely permanent.

Good tones by redevelopment are obtained only by using blue-black to pure black prints of considerable vigor. They must be exactly timed and fully developed. They must be completely freed from hypo before bleaching and the bleaching and redeveloping solutions must be fresh and strong.

Sulphide Toning changes metallic silver to brown silver sulphide by first converting it to a silver salt and then precipitating the silver sulphide through the action of any soluble sulphide. The bleach forms silver ferricyanide in the print and a typical formula is:

BLEACH

Potassium ferricyanide	1 oz.	30 g
Potassium bromide	1 oz.	30 g
Water to make	20 oz.	600 cc

The print must be free of hypo because a mixture of hypo and ferricyanide, which is the well-known Farmer's reducer, would remove the image entirely.

The print should be left in the bleaching solution until the last trace of black has disappeared from the deepest shadows, then rinsed for 2 or 3 minutes, after which it is redeveloped.

REDEVELOPER

Sodium sulphide	2 oz.	60 g
Water	5 oz.	150 cc

(Note that this chemical is sodium sulphide, not sulphite.) For use take $\frac{1}{2}$ ounce of the stock solution in 10 ounces of water. If it does not redevelop the picture to a rich sepia in a few seconds, it is a sign that the solution is stale or exhausted. The bleaching solution may be kept for future use if stored in a brown bottle or kept in the dark. The diluted sulphide redeveloper should be discarded after being used. It has a very offensive odor, and graduates, trays, and sinks that have been used for sulphide redeveloping should be thoroughly washed with a final rinse in water in which a little permanganate of potash has been dissolved, which acts as a deodorizer. The odor of sodium sulphide is unpleasant, somewhat dangerous, and may cause headache, and it will spoil sensitive materials that are exposed to it. It should, therefore, not be used in any workroom where sensitive materials are stored.

The redeveloped print must be hardened for 5 minutes to prevent blisters, and then washed for one-half hour in running water. For the hardening bath, take 1 ounce of hardener F-1a (see page 166) diluted with 16 ounces of water.

Let the print dry after fixing and washing, before toning, to avoid uneven results and, in some cases, muddy tones.

As iron and ferricyanide solutions, in combination, form Prussian blue, the least trace of iron from the water pipes, or from a cracked enamel tray, may cause blue spots or stains on the print. Use a filter on the faucet, and if an enameled tray is used, be sure that it is in good condition. Dilute hydrochloric acid applied to the blue spots, after the print is thoroughly dry, will remove the spots without injury to the print. Washing is then necessary to remove the acid.

A richer and colder sepia may be obtained by immersing the print in the sulphide redeveloping solution for about 3 minutes before bleaching. Leave it in the redeveloping solution face downwards for 3 minutes, then rinse in water and quickly transfer to the bleacher, when the toning is carried out as usual. This method will give a very pleasing color.

Thiocarbamide used instead of sodium sulphide for darkening after bleaching, avoids the offensive odor and the danger of spoiling sensitive materials which is always attendant upon the use of sulphide.

THIOCARBAMIDE REDEVELOPER

Thiocarbamide (10 per cent solution)	$\frac{1}{2}$ oz.	7 cc
Caustic soda (10 per cent solution)	$\frac{1}{2}$ oz.	14 cc
Water to make	8 oz.	224 cc

Thiocarbamide will not redevelop except in an alkaline solution, so if any acid bleacher is used in place of the one given above, the print must be very thoroughly washed after bleaching.

When the sepia obtained by redeveloping is too yellow, the print may be saved by bleaching in the darkroom in:

Copper bromide	130 gr.	8 g
Sodium bromide	2½ oz.	75 g
Water to make	10 oz.	300 cc

The bleached print is then taken into daylight and redeveloped with amidol or any clean-working developer, after which it may be re-toned.

Silver-Mercury Sulphide gives a range of warm colors from a warm brown to a brown-black which can be produced with certainty in prints that have been properly developed.

The bleaching bath is composed of two stock solutions used in varying proportions according to the color desired.

<i>Stock Solution A</i>		
Potassium ferricyanide	2 oz.	60 g
Potassium bromide	1 oz.	30 g
Water to make	20 oz.	600 cc
<i>Stock Solution B</i>		
Mercuric chloride	½ oz.	15 g
Water to make	20 oz.	600 cc

Use the various quantities of stock solutions A and B specified below for each ounce of working solution.

A, 60 minims	for a rich, warm brown tone
A, 60 minims	} for a cool brown tone
B, 30 minims	
A, 40 minims	} for a very deep brown tone
B, 40 minims	
A, 40 minims	} for a brown-black tone
B, 80 minims	

Intermediate proportions will yield corresponding tones.

Whenever any of solution B, the mercuric chloride solution, is used in the bleaching bath, a 1 per cent solution of pure hydrochloric acid must be used for rinsing the print between the bleaching and the sulphiding. Wash the print in two or three changes of water after bleaching and then place it in two or three successive baths of the dilute hydrochloric acid. Then wash again for a few minutes before sulphiding the prints in the regular sulphiding solution or the thiocarbamide redeveloper.

When mercuric chloride is added to the bleaching bath the print is intensified a little, the degree of intensification depending on the amount of solution B that is used. In making prints allowance must be made for the increase in strength by giving slightly less exposure. When the full quantity of mercuric chloride is used (80 minims to each ounce of working solution), three-quarters of the normal exposure should be given in making the print, and the subsequent intensification will bring it up to normal strength. Other concentrations of the mercury require corresponding shortening of the time. This toning method might be used for prints that are a little too light and would be improved by intensification.

THE ARTURA IRIS TONER. — This works well with other papers, and it is possible with this formula to get exactly the same sepia tone on both chloride and bromide papers.

The prints need not be washed after fixing any longer than is necessary to eliminate the acid from the fixing bath.

Solution No. 1

A: Distilled or rain water (boiling)	128 oz.	3900 cc
Hypo	16 oz.	480 g
Powdered alum	2 oz.	60 g

Boil the above for 2 minutes, allow it to cool and then add:

Sodium phosphate	2 oz.	60 g
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At this point, test the bath with red litmus paper which should turn blue within 1 minute. If it does not, heat the bath again and add sodium phosphate in 2-ounce quantities until the solution has become slightly alkaline. Then dissolve:

B: Silver nitrate	60 gr.	4 g
Water	1 oz.	30 cc
and Potassium bromide	180 gr.	12 g
Water	1 oz.	30 cc

Pour the bromide solution into the silver solution and add the resulting mixture, precipitate and all, to the hypo-alum solution after it is cool. If the silver and bromide solutions are added to the hypo-alum bath while it is still hot, it will turn dark. It is necessary to have the water at boiling point when the hypo and alum are being mixed, but the silver and the bromide solutions must not be added until the hypo-alum solution has cooled.

Solution No. 2

Gold chloride	15 gr.	1 g
Water	2 oz.	60 cc

The gold chloride is bought in a sealed glass tube. Soak off the paper label and drop the tube into a graduate containing the required quantity of water and break the tube in the graduate with a stirring rod. When the gold chloride is all dissolved, strain or filter out the fragments of glass.

When ready to tone, take as many ounces of solution No. 1, to which the silver and bromide solutions have been added, as are needed for the number of prints to be toned, and add 1 dram of gold solution to each 16 ounces of the hypo-alum bath. The quantity given, 128 ounces (3900 cc), is sufficient to tone about one gross of 5 by 7 inch prints or the equivalent in other sizes. It is advisable to make up a fresh bath when this number of prints has been toned rather than to attempt to renew its strength by the addition of gold.

The entire lot of prints should be toned together, keeping them well separated. Tone at 120° to 125° F. Do not begin toning at a lower temperature than 120°. Thick rubber gloves are advised.

Toning will take about 20 minutes. The bath should be slightly alkaline as tested with litmus paper. If the bath is too cold the gold tone will predominate; if too hot, the sulphur tone will predominate. Examine prints by transmitted light, and when all black has been removed from the deepest shadows, it is safe to assume that the final color has been obtained. Sponge the prints to remove sediment, fix for 5 minutes in a regular fixing bath, and wash as usual.

HYPO-ALUM TONING. — When an acid-alum-hypo bath is old or improperly mixed, precipitated sulphur makes the bath milky, and it has a decided toning action on the silver image. This action has led to the use of alum to throw down sulphur and give a bath, which when used cold would tone prints overnight, or if used hot (110° F.) would tone them in about one-half hour.

A number of slightly varying formulas are given for this hypo-alum mixture, a typical one being:

Hot distilled or rain water (125° F.)	128 oz.	3900 cc
Hypo	16 oz.	480 g
Alum	4 oz.	120 g

In order to ripen the bath and to counteract the reducing action of a freshly mixed hypo and alum solution, a number of waste prints may be placed in it. Another way to ripen the solution is to add to it, when cool, the following:

Distilled or rain water	1 oz.	30 cc
Silver nitrate	60 gr.	4 g
Table salt	60 gr.	4 g

Stir the mixture well. Then heat it to about 130° F. and allow it to cool again. When required for use, the bath should be heated to about 100° to 110° F. The solution should not be filtered or decanted, but it should be well stirred up before use and it works better as it becomes older. It may be strengthened from time to time with fresh solution. Toning will take from 20 to 30 minutes. The prints should be given an alum bath to harden the emulsion if they have not already been fixed in an alum hardening and fixing bath. When toning is complete, the prints may be placed in a tepid, 5 per cent solution of alum. Then the sediment should be carefully sponged off and the prints washed thoroughly.

A gas ring or electric heater may be used to keep the solution hot during toning, but the prints should not be allowed to come in contact with the bottom of the tray if it is in contact with the heat, as this would result in uneven toning. The tray containing the prints can be stood in a larger metal tray filled with water, the corners of the inner tray being supported so that the water can pass freely under it.

URANIUM TONING.—Treatment of a silver image with a mixture of a soluble uranium salt and ferricyanide of potassium results in brown to red images, the color being dependent on the ratio of the two salts and the duration of toning. A simple formula is:

<i>Solution A</i>		
Uranium nitrate	38 gr.	2.5 g
Water	8 oz.	240 cc

Mix this first and then add slowly to the following, separately prepared solution:

<i>Solution B</i>		
Potassium ferricyanide	38 gr.	2.5 g
Glacial acetic acid	96 minims	6 cc
Water	8 oz.	240 cc

Mix just before use. Or the prints may be immersed in solution B until bleached, then well washed, and placed in solution A until the desired color is obtained. This toner will yield good colors that are permanent. As there is some slight intensification, this toner should be used for prints that are slightly lacking in strength.

SELENIUM TONING.—Toning with selenium is an old method of getting various shades of sepia.

Powdered selenium	15–70 gr.	1–4.6 g
Sodium sulphide	768 gr.	50 g
Water	16 oz.	480 cc

This gives various shades of sepia to purplish red tones. Heat the solution till the selenium dissolves, and dilute as required for use. The less selenium is used in the bath, the more sepia the color. On diluting the bath, some selenium is precipitated and the solution should be filtered, or the prints, after toning, passed through two or three baths of 1 per cent solution of sodium sulphide.

Another formula (Valenta) is:

Selenium	127 gr.	8 g
Sodium sulphide	3½ oz.	96 g
Water	16 oz.	480 cc

Heat until dissolved, dilute with five or six times its volume of water, and add pyrocatechin, 1 per cent solution, 150 to 300 minims to 16 ounces. If the whites are tinged, pass the prints through weak baths of acid sulphite of soda.

The manufacturers of Mimosa papers suggest that if the selenium bath is neutralized with boric acid, there is no precipitation of the selenium. The addition of ammonia reduces the staining of the whites, which may be removed by a 10 per cent solution of potassium metabisulphite.

COPPER TONING FOR BROWNS AND REDS.—Copper toning gives a great variety of color inexpensively; it does not alter the vigor of the prints, and its results are permanent. Almost any shade from a warm black or dark brown to a pure, red chalk can be obtained, the color depending on the length of time the bath is allowed to act. Two stock solutions are used:

<i>Stock Solution A</i>		
Copper sulphate	60 gr.	4 g
Potassium citrate (neutral)	240 gr.	16 g
Water to make	20 oz.	590 cc
<i>Stock Solution B</i>		
Potassium ferricyanide	50 gr.	3.3 g
Potassium citrate (neutral)	240 gr.	16 g
Water to make	20 oz.	590 cc

For use, mix equal parts. If the prints are pinkish in the highlights, use more citrate in either one of the stock solutions.

Toning may be stopped at any point by removing the print and washing it well. If a sepia tone is wanted, the print may be soaked for about 5 minutes in 2 per cent nitric acid and washed. It may then be sulphided in the usual bath. The redder the copper tone, the redder the sepia. If, however, the print is simply toned in the bath as given, red tones may finally be obtained direct.

BARTOLOZZI RED.—The following solution is recommended for producing rich red tones. Make up a saturated solution of ammonium carbonate by adding 3 ounces of the crushed salt to 10 ounces of cold water, shaking as often as possible for several days. Then make up the following solution.

Ammonium carbonate, saturated solution	1 oz.	30 cc
Copper sulphate	10 gr.	0.6 g
Potassium ferricyanide	25 gr.	1.5 g

Any precipitate which forms when the copper is added to the carbonate will be redissolved. The solution should be perfectly clear, but should be used immediately, as it spoils on standing. Toning should be continued until the deepest shadow is converted, and then for 1 minute longer. The print should then be washed for 10 minutes or, preferably, immersed in the acid-hypo fixing bath to remove any unconverted silver salt, and then washed. Pink stain in the whites is easily removed by treating with a 1 per cent solution of ammonia water. If it is used stronger than this it will destroy the color. Owing to the alkaline condition of this bath, it produces red tones more quickly than does the one containing neutral potassium citrate.

CRIMSON TONES ON SEPIA PRINTS.—A print toned in hot hypo-alum may be further toned to a rich crimson by gold toning.

After the print has been sepia toned and thoroughly washed, it should be

put through a salt bath made up by dissolving 1 ounce of table salt (sodium chloride) in 32 ounces of water. Rinse, then tone in:

<i>Solution A</i>		
Gold chloride	15 gr.	1 g
Water	15 oz.	450 cc
<i>Solution B</i>		
Potassium sulphocyanide	90 gr.	6 g
Water	15 oz.	450 cc

Add either one to the other, stirring slowly, so as not to precipitate the gold. This 30-ounce bath will tone about eighteen 8 by 10 inch prints or their equivalent. To strengthen the bath it is necessary to use both chemicals. To make solution A into a stock solution, dissolve 15 grains of gold chloride in 2 ounces of water, and for solution B, dissolve 90 grains of potassium sulphocyanide in 2 ounces of water. Add equal quantities of solutions A and B to the old bath, the number of drams of each depending upon the number of prints to be toned. Using this stock solution avoids adding more water to the bath. Prints tone in about 10 minutes and should then be fixed in acid hypo for 20 minutes, and washed.

Gold toning may also be used for improving the color of greenish or rusty black prints and for obtaining blueish tones. This is used on black-and-white bromide or chlorobromide prints to obtain a colder tone. Make up the following solution:

Ammonium sulphocyanide	130 gr.	9 g
Gold chloride	9 gr.	0.6 g
Boiling water	20 oz.	590 cc

Use as soon as it is cool. Either immerse the print in the solution or place the wet print face upwards on a sheet of glass, squeegee into contact, blot off superfluous moisture, and paint the above toning solution on the print with a wad of cotton or a broad, flat brush. When the desired tone is reached, wash well and dry.

Red, blue, green, and other colors may be obtained by toning bromide and chlorobromide prints. The success of the toning depends upon starting with a print of a good black color, developed as far as possible, and quite black when viewed by transmitted light.

BLUE TONES.—Grayish blue tones are pleasing for snow scenes or a slightly brighter and more greenish blue tone for seascapes. There are several formulas for obtaining blue tones on bromide and chlorobromide papers, many of which depend on the formation of Prussian blue by first converting the silver image to a salt and then forming the blue precipitate by means of iron. A reliable formula and one that is also particularly effective

for blue transparencies and lantern slides is Kunz's modification of a formula devised by C. Winthrope Somerville, as follows:

Bleach the print in:

Water	10 oz.	300 cc
Potassium ferricyanide	100 gr.	6.6 g
Ammonia water (sp. gr. 0.88)	100 minims	6.6 cc

Wash well and tone in the following, rocking constantly:

Water	10 oz.	300 cc
Ferrous sulphate	100 gr.	6.6 g
Hydrochloric acid, C.P.	50 oz.	3.3 g

Wash free from stain and fix in a 10 per cent hypo solution containing 50 grains of boracic acid to every ounce of solid hypo, or in a plain hypo bath with sodium bisulphite.

The above formula produces a rather bright, greenish blue. A grayer blue may be obtained by using the following formula:

Ammonium iron alum (10 per cent solution)	175 minims	11.5 cc
Potassium oxalate (10 per cent solution)	440 minims	29 cc
Tartaric acid (10 per cent solution)	70 minims	4.6 cc
Potassium ferricyanide (10 per cent solution) ..	240 minims	15 cc
Water	16 oz.	480 cc

As soon as the prints have assumed the desired color they should be well washed, fixed in a 5 per cent solution of hypo, washed again, and immersed for 2 minutes in a 1 per cent solution of sulphuric acid.

This process reduces density slightly, so original prints should be a trifle dark.

BLUE WITH INTENSIFICATION.—Rich blue tones are obtained by iron toning. This process gives slight intensification of the print. Two popular formulas for iron toning are:

Ferric ammonium citrate (10 per cent solution)	2 oz.	60 cc
Potassium ferricyanide (10 per cent solution)	2 oz.	60 cc
Acetic acid (10 per cent solution)	20 oz.	600 cc

Another similar formula is:

Ferric ammonium citrate	6 gr.	0.4 g
Potassium ferricyanide	6 gr.	0.4 g
Nitric acid	12 minims	0.75 cc
Water	16 oz.	480 cc

The well-washed print is immersed in either of these solutions, in which it will tone rapidly to a rich blue. Wash in several changes of water until the whites lose the stain acquired during the toning. It is better to prolong the washing a little beyond the visible clearing.

BLUE WITH THIOCARBAMIDE.—This gives a soft, grayish purple rather than a vivid blue, and is good for snow scenes showing white snow, blue sky, and blue shadows, for the color suggests a blue atmosphere. Three stock solutions are made up as follows:

<i>Solution A</i>		
Thiocarbamide	50 gr.	3.5 g
Water	8 oz.	240 cc
<i>Solution B</i>		
Citric acid	50 gr.	3.5 g
Water	8 oz.	240 cc
<i>Solution C</i>		
Gold chloride	15 gr.	1 g
Water	8 oz.	240 cc

For use, take 1 ounce of each to 10 ounces of water. This quantity will tone from two to four 11 by 14 inch prints in about 20 to 30 minutes. The mixed solution will not keep more than a day or two, but the stock solutions will keep well.

This thiocarbamide toner gives a rather subdued bluish tone on chloride papers and a more greenish tone on chlorobromide. If thiocyanate is substituted for thiocarbamide, more purplish shades are obtainable. Slight intensification will take place with some papers. This intensification is much more likely to occur with chloride and chlorobromide emulsions than it is with straight bromide emulsions.

The above method was suggested by Adolf Fassbender. Dr. D. J. Ruzicka recommends the following procedure which is particularly adapted to chloride papers, and works equally well on chlorobromide although giving more purplish tones, but is not so well suited to bromide. The print should be warm-toned and slightly soft. The subsequent toning adds the necessary crispness to the picture.

Although the regular metol-hydroquinone developers can be used, the developer preferred by Dr. Ruzicka contains Adurol which is also known as mono-chlorhydroquinone. A suggested formula is:

<i>Stock Solution</i>		
Adurol	32 gr.	2 g
Sodium sulphite	128 gr.	8 g
Sodium carbonate	128 gr.	8 g
Potassium bromide	4 gr.	0.25 g
Water to make	16 oz.	480 cc

For use, take 1 part stock solution to 9 parts water.

Following development which usually takes about 2 minutes at 70° F., the print is placed immediately in an acetic acid stop-bath consisting of 1¼ ounces of 28 per cent acetic acid to 32 ounces of water to check development, and should then be fixed in a fresh hypo bath in which there is no alum, for the use of an alum hardener in the fixing bath will prevent toning. A little potas-

sium metabisulphite may be used. A good fixing bath suggested for Tuma-Gas paper is:

Water	100 oz.	3000 cc
Hypo	24 oz.	720 g

When dissolved, add the following solution:

Water	20 oz.	600 cc
Bisulphite of soda	3 oz.	90 g

Prints intended for toning must be very thoroughly washed to get rid of every trace of hypo.

The stock solutions for toning are made up as follows:

Gold chloride	15 gr.	1 g
Distilled water	7½ oz.	225 cc

This stock solution should be kept in a brown bottle.

Thiocarbamide	60 gr.	4 g
Distilled water	7½ oz.	225 cc

To make the working solution, take 1 pint of water and add to it 2 ounces of the thiocarbamide solution. Then add slowly, while stirring, 2 ounces of the gold chloride solution. Add another pint of water, and then add, drop by drop, 10 drops of sulphuric acid, while stirring the solution. The mixing of these stock solutions should be done slowly and thoroughly.

Prints will tone in this solution in from 10 to 15 minutes at about 70° F. The quantity given will tone about six rather light prints or four dark ones. Wash for one-half hour after toning.

RED TONES WITH THIOCARBAMIDE AND GOLD. — To get a red tone, the print is first sepia toned in the usual bleaching and redeveloping solutions. When the sulphided print is placed in the blue toner, a distinctive red tone will be attained in from 20 to 30 minutes.

INDIRECT GREEN PROCESS. — Immerse the print in the following for 3 to 5 minutes:

Potassium bichromate	5 gr.	0.3 g
Potassium ferricyanide	25 gr.	1.6 g
Water	2 oz.	60 cc

The longer the immersion, the lighter will be the green. Wash free from bichromate stain and tone in:

Cobalt chloride.....	20 gr.	1.3 g
Ferrous sulphate	5 gr.	0.3 g
Hydrochloric acid	20 minims	1.2 cc
Water	2 oz.	60 cc

Toning is rather prolonged. Cobalt ferrocyanide is deposited on the black silver image, imparting to it a particularly fine shade of green.

If the hydrochloric acid is replaced by 30 minims of glacial acetic acid, an emerald green is obtained.

After toning, the print is washed for 5 to 10 minutes and placed in a hypo bath for about 1 minute and again washed. The resulting print is quite permanent.

If the cobalt chloride is replaced by 1 grain of vanadium chloride dissolved in 1 ounce of water, and 1 grain of ferric chloride with 10 minims of nitric acid instead of the ferrous sulphate and hydrochloric acid, an olive green is obtained, the depth of color depending on the extent to which the print has been bleached. There is a continuing action which takes the tone up into the light green stage if toning is not stopped soon enough.

A NON-POISONOUS GREEN TONER.—H. E. Smith is responsible for a formula which contains no poisonous chemicals.

<i>Solution A</i>		
Potassium ferricyanide	180 gr.	12 g
Distilled water	20 oz.	600 cc
<i>Solution B</i>		
Vanadium chloride, stock solution	3½ drams	12 cc
Ferric ammonium citrate (green scales) ..	45 gr.	3 g
Sodium citrate (neutral) (Merck)	2½ oz.	75 g
Ammonium chloride	90 gr.	6 g
Hydrochloric acid, C.P.	1½ oz.	45 cc
Distilled water	10 oz.	300 cc

The vanadium chloride stock solution is made by mixing 1 ounce of vanadium chloride, as purchased (Merck's syrupy), with 5 drams of C.P. hydrochloric acid and then adding distilled water to make 2 ounces, 90 minims in all. In making up solution B, first add the hydrochloric acid to the vanadium solution. Then dissolve the ferric citrate, sodium citrate, and ammonium chloride in the 10 ounces of water and mix the two. The solution should be a dull mauve blue, not green—until mixed with solution A. Both A and B solutions will keep for months.

To mix the toning solution, take 1 part of solution A with 4 parts of water and, separately, 1 part of solution B with 4 parts of water. The two weak solutions when mixed together form the toning bath. Prints tone in from 4 to 8 minutes. Rock constantly, then wash in five changes of water, each of 2 minutes; give a bath of 1 to 50 hydrochloric acid for 2 minutes, and finally wash for about 15 minutes in seven or eight changes of water. This process does not intensify the print and the color is permanent.

DE-SULPHIDING TONED PRINTS.—Sulphide-toned prints may be restored to their original black color by bleaching in acid permanganate and then redeveloping. To a solution containing 2 parts of strong hydrochloric acid in 100 parts of water, add a small quantity of potassium permanganate solution. Not *vice versa*.

Bleach the prints in this solution, wash for 5 minutes, and treat with a 5 per cent potassium metabisulphite solution to remove the stain. Wash again for 10 minutes and redevelop with amidol.

CHAPTER XII

SILVER PRINTING-OUT PAPERS

The salted paper process was invented by William Henry Fox-Talbot, and his picture of Laycock Abbey, made in 1835, is the oldest example of photography. The process was announced to the Royal Institution on January 31, 1839, and patented the following year as part of his *Calotype* process. Paper was immersed in a weak solution of salt, dried, and then just before use sensitized by immersion in a solution of silver nitrate. When dry it was printed under a negative by inspection until the visible image was dark enough, then fixed in hypo and washed and dried. The color of the print was improved by toning with gold chloride by Le Gray in 1849. Albumen was later added to the salting solution to give the paper a gloss finish and to keep the silver salts on the surface of the paper, and for about 30 years, until the introduction of other papers, albumen paper was the only printing process in general use. Paper coated with albumen was commercially available and the photographer sensitized it in a solution of silver nitrate just before use. Collodion was sometimes used instead of albumen, but it was not until about 1885 that the process of using gelatin with the chloride gave the paper such keeping qualities that it could be coated and sensitized commercially and sold all ready for printing. These papers formed a visible image during printing and came to be known as printing-out papers (P.O.P.) to distinguish them from the later developing-out papers which came into more general use, in which the image was latent and invisible until developed.

SALTED PAPERS. — In this process the original surface of the paper is practically preserved, the sensitive salts being more or less in the fibers of the paper, in contradistinction to those processes in which they are suspended in an emulsion. In all cases, however, a size should be used to prevent too deep penetration into the paper. Various sizes may be used; starches, such as arrowroot, etc., tend to give brownish tones, while gelatin tends rather to more blueish tones. The size may be applied to the paper first, but it is frequently more convenient to incorporate the salts with it:

Arrowroot	154 gr.	20 g
Water	12 oz.	750 cc

Rub the arrowroot into a cream with a little of the water; bring the remainder of the water to the boil, add the arrowroot cream slowly with con-

stant stirring, and continue heating until a translucent liquid is formed. Then add:

Ammonium chloride	107 gr.	14 g
Sodium carbonate (crystals)	177 gr.	23 g
Citric acid	54 gr.	7 g
Water	4 oz.	250 cc

As effervescence takes place when mixing this latter solution, it is advisable to make it in a fairly large beaker before adding it to the arrowroot. It is as well, though not necessary, to boil this solution for 5 minutes to expel the carbonic acid. The salted arrowroot mixture should be strained through fine muslin while hot. Immerse the paper in the warm solution for 2 minutes, and hang up to dry. When nearly dry, again immerse for the same time, and hang up by the opposite corners to those previously used. As an alternative to this, the paper may be pinned by two corners to a flat board, and the salting solution freely applied with a broad flat brush. The solution is allowed to dry, and the operation is then repeated. Increase of the arrowroot by 50 per cent increases brilliancy of the surface. For a gelatin size one of the following may be used:

Gelatin	15 gr.	2 g
Ammonium chloride	138 gr.	18 g
Sodium citrate	138 gr.	18 g
Water	16 oz.	1000 cc

Or:

Gelatin	34 gr.	4.5 g
Ammonium chloride	138 gr.	18 g
Sodium citrate	165 gr.	21.5 g
Salt	54 gr.	7 g
Water	16 oz.	1000 cc

Or:

Gelatin	54 gr.	7 g
Ammonium chloride	108 gr.	14 g
Water	16 oz.	1000 cc

The more gelatin used, the higher the gloss of the resultant prints. The more citrate used, the more rapid the paper, with less contrast. Soak the gelatin in the water, melt by heat, and add the salts.

For mat and semi-mat lac papers, shellac with gelatin is used as a size. Unfortunately, bleached shellac is quite insoluble in aqueous mediums, and its solubility is very variable, unless freshly bleached:

Bleached lac	637 gr.	83 g
Borax	323 gr.	42 g
Water	12 oz.	750 cc

The lac should be broken up small, added to the borax solution, and the mixture boiled until it has dissolved, or not less than 2 hours, water being added from time to time to replace that which boils away. Then take:

Bleached lac	384 gr.	50 g
Sodium phosphate	192 gr.	25 g
Water	12 oz.	750 cc

Boil in the same way as above, mix the solutions, and add:

Gelatin	353 gr.	46 g
Water	8 oz.	500 cc

Allow the gelatin to soak in the water for 30 minutes, and melt by heat. Filter the mixture through fine linen. Immerse the paper for 2 minutes, and hang up to dry. When nearly dry, again immerse, and hang up by the opposite end. To salt this, float the paper on:

Ammonium chloride	177 gr.	23 g
Magnesium lactate	177 gr.	23 g
Water	16 oz.	1000 cc

Then hang up to dry. Either the borax-lac or phosphate-lac may be used alone with half the above quantity of gelatin solution.

Sensitizing.—After paper has been sized and salted by any of the above processes, it is dried and may then be kept in stock. Just before use it must be sensitized and then dried again before printing. The sensitized paper does not keep more than a few hours before beginning to deteriorate. All plain papers are most satisfactorily sensitized by brushing on the silver solution, not floating. Either a plain silver solution may be used, such as:

Silver nitrate	1 oz.	62.5 g
Water	8 oz.	500 cc

Or an acid one:

Silver nitrate	560 gr.	73 g
Citric acid	400 gr.	52 g
Water	8 oz.	500 cc

Or an alkaline one:

Silver nitrate	245 gr.	32 g
Ammonia	q. s.	q. s.
Water	4 oz.	250 cc

Dissolve the silver, add enough strong ammonia to form a clear solution, and then add:

Silver nitrate	245 gr.	32 g
Water	4 oz.	250 cc

If necessary add a little more ammonia to clear up any precipitate formed. Papers thus prepared will not keep more than a few hours, but they print very rapidly, and give very vigorous prints. It is better to use the plain silver solutions, and fume the paper with ammonia just before use. This can be effected by cutting the paper to size and pinning to the inside of the lid of a plate box, on the bottom of which is a sheet of blotting paper wet with a 10 per cent solution of ammonia. About 10 to 15 minutes will be sufficient. Instead of the liquid ammonia, coarsely powdered ammonium carbonate may be used, and then the paper should be fumed for 30 minutes.

Printing upon salted paper requires a very vigorous negative. The printing should be carried rather deep and the prints washed with repeated changes of water until no milkiness is seen in the water, or a 5 per cent solution of salt may be used, and the prints then washed for 10 minutes.

Toning may be effected with either gold or platinum. Weak baths give the best results, such as:

Borax	54	gr.	7	g
Gold chloride	0.85	gr.	0.11	g
Hot water	16	oz.	1000	cc

Sodium phosphate or acetate may be used instead of the borax, and the tones vary from sepia to purple, according to the duration of toning. As the prints always dry a little colder, or bluer, in tone than when wet, allowance should be made for this.

A suitable platinum bath is:

Potassium chloroplatinite	2.3	gr.	0.3	g
Citric acid	61	gr.	8	g
Salt	19	gr.	2.5	g
Hot water	16	oz.	1000	cc

After toning, the prints should be immersed in a 1 per cent solution of common salt to stop the toning action, fixed in a 5 per cent solution of hypo, and well washed.

If resin-sized paper be used, the following will give black and sepia tones direct. For black tones:

Sodium phosphate	307	gr.	40	g
Borax	154	gr.	20	g
Sodium carbonate	77	gr.	10	g
Sodium chloride	38.5	gr.	5	g
Potassium bichromate	0.08	gr.	0.01	g
Water	16	oz.	1000	cc

For sepia tones:

Sodium phosphate	154	gr.	20	g
Borax	307	gr.	40	g
Sodium chloride	38.5	gr.	5	g
Potassium bichromate	0.6	gr.	0.08	g
Water	16	oz.	1000	cc

Immerse the paper for 20 to 40 seconds, and dry. Sensitize with:

Silver nitrate	384	gr.	50	g
Lead nitrate	384	gr.	50	g
Water	16	oz.	1000	cc

Neutralize this with sodium carbonate before use.

The following method is given by Namias:

Gelatin	192	gr.	25	g
Zinc chloride (crystals)	46	gr.	6	g
Citric acid	38½	gr.	5	g
Ammonia	46	minims	6	cc
Water	16	oz.	1000	cc

Soak the gelatin in one-half the water, and dissolve with heat; dissolve the acid in the remainder of the water, add the ammonia and then the zinc, mix the two solutions and filter. Tartaric acid may be used instead of the citric, and darker brown tones are obtained. Immerse the paper in the warm solution and dry. Sensitize by brushing over with either of the following solutions:

Silver nitrate	922	gr.	120	g
Citric acid	384	gr.	50	g
Glycerin	384	minims	50	cc
Water	16	oz.	1000	cc

Or:

Silver nitrate	922	gr.	120	g
Ammonia		q.s.		q.s.
Water	8	oz.	500	cc

Use enough ammonia to form a clear solution, and then add:

Lactic acid, pure syrupy	384	minims	50	cc
Water to make	16	oz.	1000	cc

Greater contrasts can be obtained by adding a little 5 per cent solution of potassium bichromate. A more rapid paper is obtained with the following:

Silver nitrate	768	gr.	100	g
Uranium nitrate	384	gr.	50	g
Lactic acid	384	minims	50	cc
Water	16	oz.	1000	cc

The following gives sepia tones, but the stock solution will not keep:

Ammonio-citrate of iron (green)	512	gr.	66.6	g
Water	5	oz.	333	cc
Potassium bichromate	12.3	gr.	1.6	g

Dissolve and add:

Silver nitrate	256	gr.	33.3	g
Water	11	oz.	667	cc

After printing, this paper should be immersed in a 1 per cent solution of oxalic acid, then washed, and fixed in a 2 per cent hypo bath.

A casein paper can be made as follows:

Ammonium chloride	31 gr.	4 g
Sodium citrate (neutral)	310 gr.	40 g
Water	6½ oz.	400 cc

Dissolve and add:

Casein	310 gr.	40 g
Ammonia	384 minims	50 g
Water to make	5½ oz.	350 cc

Warm this until dissolved, then add:

Silver nitrate	538 gr.	70 g
Water	16 oz.	1000 cc

This paper will not keep well, but can be made more stable by immersion in 3 per cent solution of citric acid.

SENSITIZING LEATHER, FABRICS, AND WOOD. (Cobenzl).—*Fabrics* like silk, linen, and cotton are sensitized by immersion in the following:

Ammonium chloride	154 gr.	20 g
Gelatin	38 gr.	5 g
Water	13 oz.	800 cc

Soak the gelatin in the water, add the chloride, melt with heat, and add to:

Soluble starch	154 gr.	20 g
Water	3 oz.	200 cc

The material should be immersed in this until thoroughly soaked, then hung up to dry; if the fabric is thick and soaks up much of the liquid, more water should be added. When dry, it is silvered with:

Silver nitrate	3 oz., 134 gr.	205 g
Citric acid	791 gr.	103 g
Water	16 oz.	1000 cc

The fabric should be laid on the bottom of a large dish, a glass rod placed on the top, the liquid poured over, and the rod rolled to and fro; this saturates the cloth without the necessity of touching it with the fingers. Artificial light should be used, and the drying should be as rapid as possible. After printing, the material should be immersed in salt solution, washed and toned, as usual, if desired.

Thin veneer *wood* can be sensitized. Maple and plane give the best results; pear is less satisfactory. The wood should be immersed for at least 5 minutes in:

Soft gelatin	288 gr.	37.5 g
Water	16 oz.	1000 cc

Soak, melt by heat, and add:

Formaldehyde	58 minims	7.5 cc
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After drying with moderate heat, immerse for 5 minutes in:

Hard gelatin	192 gr.	25 g
Soluble starch	768 gr.	100 g
Ammonium chloride	77 gr.	10 g
Water	16 oz.	1000 cc

Again dry, and sensitize in:

Silver nitrate	768 gr.	100 g
Citric acid	637 gr.	83 g
Water	16 oz.	1000 cc

This must be dried in the dark and then printed by daylight under a strong negative. After printing, wash and tone as with a paper print.

Another method of working is to treat the wood with a 5 per cent solution of alum instead of formaldehyde, to harden the colloid bodies. The next operation is a bath of:

White soap	35 gr.	2.5 g
Gelatin	35-53 gr.	2.5-3.25 g
Alum	35 gr.	2.5 g
Water	4 oz.	125 cc

The gelatin is swelled in some of the water. A hot soap-flake solution is made with a little more of the water and the swelled gelatin is dissolved in this by heat. The alum is dissolved in the rest of the water and the solution is added to the soap and gelatin solution slowly, while stirring it well. It should be applied to the wood while hot.

The coated wood must dry thoroughly, and when it is dry a 2 per cent solution of sal ammoniac is applied and the wood is again allowed to dry thoroughly. The actual sensitizer is a 20 per cent solution of silver nitrate in water which must be applied under artificial light and dried in the dark. Printing frames may need to be modified to accommodate thick pieces of wood and some experiments will have to be made, using an actinometer, to determine the correct printing time.

The sensitizing of leather, such as split calfskin, is an easy matter, but it will not keep after sensitizing. It is advisable to coat it first with plain collodion and then with a collodio-chloride emulsion. Or the following may be used:

Hard gelatin	19	gr.	2.5	g
Soluble starch	77	gr.	10	g
Potassium bromide	67	gr.	8.75	g
Cadmium bromide	67	gr.	8.75	g
Ammonium chloride	19	gr.	2.5	g
Cadmium iodide	19	gr.	2.5	g
Water	16	oz.	1000	cc

Saturate the material, dry quickly, and sensitize in:

Silver nitrate	307	gr.	40	g
Citric acid	384	gr.	50	g
Water	16	oz.	1000	cc

Clean, brilliant negatives and short exposure to a bright light are required; enlargements may also be made. After exposure the material should be immersed in a 5 per cent solution of ammonium chloride, and developed with:

Pyro	19	gr.	2.5	g
Hydroquinone	58	gr.	7.5	g
Citric acid	77	gr.	10	g
Sodium sulphite	260	gr.	34	g
Water	16	oz.	1000	cc

Temperature 95° F. (35° C.). As soon as the image has well appeared, fix in an acid bath, and tone with gold.

For an emulsion for *fabrics*, either of the following may be used:

Hard gelatin	2 oz., 47	gr.	120	g
Water	23	oz.	1300	cc

Dissolve and add:

Zinc bromide (crystals)	332	gr.	43	g
Cadmium iodide	7.7	gr.	1	g
Cadmium chloride	23	gr.	3	g

Next add, at 158° F. (70° C.):

Alcohol	8	oz.	500	cc
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Then add, in the darkroom:

Silver nitrate	384	gr.	50	g
Water	770	minims	100	cc

Finally, add:

Alcohol	770	minims	100	cc
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Digest for $2\frac{1}{2}$ hours at 175° F. (80° C.), and then cool down with constant stirring until the temperature is 60° F. (15° C.), when the emulsion will sink to the bottom of the vessel; this should be collected, washed, and melted with the addition of:

Sodium carbonate	1.5 gr.	0.2 g
Ammonium bromide	1.5 gr.	0.2 g
Water	$38\frac{1}{2}$ oz.	2400 cc

Melt at 85° F. (30° C.), and saturate the fabric. This can also be used for paper and gives tones ranging from red to black, according to exposure and developer.

SILVER PRINTING-OUT PAPERS. — Commercial emulsions are made by the precipitation in gelatin or collodion of silver chloride with citrate, tartrate, or oxalate of silver, which is coated upon baryta-coated paper. These papers, commonly called P.O.P. (printing-out paper), or Solio paper, have had a long vogue with portrait photographers for proofs which are purposely sent out untuned and unfixed so that they will darken after they have served their purpose of showing the customer what is in the negative.

For permanent work these papers are toned before fixing, or toned and fixed simultaneously in a combined bath. They require much less vigorous negatives than are required for salted paper, and there are contrasty papers especially prepared for weak negatives. Collodion papers give richer images than can be obtained upon gelatin papers, and they are also preferred in hot climates as they can be processed at high temperatures that would melt the coating of gelatin papers.

Silver printing-out papers must be printed considerably darker than the desired finished result, to allow for the bleaching which occurs during toning and fixing. Print until the highlights are distinctly tinted.

After printing, the paper is either separately toned and fixed, or the operation is done simultaneously in a combined bath.

Gold Toning. — The bath should be slightly alkaline, and used at a temperature of about 65° F. If the bath is acid the toned image will be too weak, while if it is too alkaline it will not tone.

GOLD TONING BATH

Sodium acetate fused	90 gr.	10 g
Borax	9 gr.	1 g
Gold chloride (1 per cent solution)	4 drams	25 cc
Water to make	20 oz.	1000 cc

The so-called gold chloride which is actually chlorauric acid ($\text{HAuCl}_4 \cdot 3\text{H}_2\text{O}$), is usually sold in 15-grain tubes from which a 1 per cent solution is made by dissolving the contents of the tube in 3 ounces of distilled water. After mixing the above solution, it should be allowed to stand for at least 1 hour before use. The used bath can be kept for further use, but it is necessary to replenish it with small quantities of gold chloride from time to time.

Fixing. — After toning, the print is rinsed in water and then fixed in hypo. The hypo bath should be kept distinctly alkaline, as with a neutral bath the gelatin is likely to swell.

FIXING BATH FOR SILVER PAPERS

Hypo	2 oz.	100 g
Sodium carbonate	9 gr.	1 g
Water	20 oz.	1000 cc

This bath becomes exhausted very rapidly and should be renewed after 3 square feet of paper have been fixed in it. To assure complete fixation, it is well to use two baths of hypo, transferring the paper after about 5 minutes in the first bath to a fresh bath.

Thiourea Toning. — This bath has the advantage that it can be used as soon as it is prepared and that it keeps well. It gives very pleasing tones and is a favorite of many workers.

THIOUREA TONER

Sodium chloride	175 gr.	20 g
Thiourea (1 per cent solution)	1 oz.	50 cc
Tartaric or citric acid	4½ gr.	0.5 g
Gold chloride (1 per cent solution)	1 oz.	50 cc
Water to make	20 oz.	1000 cc

The tartaric acid should be used for gelatin, and the citric acid for collodion papers. After toning, fix and wash as for the regular gold toning.

Platinum Toning. — The tones obtained with gold range from reds to purples and browns. Colors ranging from sepia to black, without any trace of purple or red, are obtained with platinum as the toning agent. A suitable bath is:

Potassium chloroplatinite	15.4 gr.	2 g
Dilute phosphoric acid	230 minims	30 cc
Water	16 oz.	1000 cc

The phosphoric acid may be replaced with dilute lactic acid, or acetic, tartaric, citric, oxalic acid in like quantity; or sulphuric acid, 77 minims (10 cc), may be used. The above baths keep well and give pure whites. The following acts well when freshly prepared:

Platinum perchloride	1.54 gr.	0.2 g
Sodium formate	48 gr.	6.3 g
Formic acid	9.2 minims	1.2 cc
Water	16 oz.	1000 cc

The following is also an excellent bath (Valenta):

Potassium chloroplatinite	3.8–7.6 gr.	0.5–1 g
Metaphenyldiamine	3.8–7.6 gr.	0.5–1 g
Water	16 oz.	1000 cc

For all platinum baths, the prints must be first immersed in a 10 per cent solution of common salt for 5 minutes, then rinsed; after toning, the prints should be immersed in:

Salt	2 oz.	100 g
Sodium carbonate	1 oz.	50 g
Water	20 oz.	1000 cc

Bathe for 5 minutes, and then fix in 10 per cent solution of hypo.

Namias suggested the following:

Platinum perchloride	8.5 gr.	1.1 g
Stannous chloride	7.7 gr.	1 g
Water	1 oz.	50 cc

Dissolve the platinum in one-half the water, the tin salt in the remainder, and mix the two solutions; then add:

Hydrochloric acid	384 minims	5 cc
Oxalic acid	77 gr.	10 g
Water to make	16 oz.	1000 cc

The prints should be washed in salt and water, and then in plain water before toning.

Combined Platinum and Gold Toning.—The use of gold and platinum gives pure black or blue-black tones, the blue tinge being dependent on the depth of toning with the gold. Print deeply, and immerse the print in:

Salt	192 gr.	25 g
Sodium carbonate	19 gr.	2.5 g
Water	16 oz.	1000 cc

Leave for 5 minutes, wash well, and tone in:

Borax	77 gr.	10 g
Sodium acetate (fused)	77 gr.	10 g
Gold chloride	3.8 gr.	0.5 g
Water	16 oz.	1000 cc

Then wash, and tone in:

Potassium chloroplatinite	5.4 gr.	0.7 g
Citric acid	77 gr.	10 g
Salt	123 gr.	16 g
Water	16 oz.	1000 cc

Tone until the prints look purple-black; then wash, and fix.

Another process with a mercury salt, which is open to question as to permanency, is to tone with:

Potassium chloroplatinite	23 gr.	3 g
Salt	154 gr.	20 g
Water	16 oz.	1000 cc

CHAPTER XIII

THE IRON PROCESSES

Some of the organic iron salts are light-sensitive, and many others are sensitive in the presence of organic matter. These organic ferric salts are reduced to ferrous salts when exposed to light. The photographic application of these reactions was noted by Sir John Herschel in 1842 and many processes based upon them have since been developed. Among the better known processes are the blueprint, cyanotype, kallitype, platinum, and palladium, but there have been many others of lesser importance.

THE FERROPRUSSATE PROCESS, popularly known as "blueprint," is commonly used for duplicating mechanical drawings which have been made on tracing cloth or other transparent substances which are placed right side up on the commercially obtained blueprint paper and printed through the back to obtain a print of white lines on a blue ground. Printing is slow and either sunlight or a strong artificial light is used. Print by inspection until the ground color appears bronzed. The process is completed by simply washing in three or four changes of water, until the print is cleared, showing white lines on a blue ground. The print is stable unless exposed to bright light for a long time. If it fades it can be restored by keeping it in a dark, damp place. As perspiration is always alkaline, fingerprints will show upon blueprints if they are handled with moist hands. Corrections can be made upon blueprints by using Prussian blue water color for the ground and a pen dipped in a 20 per cent solution of neutral potassium oxalate thickened with a little gum arabic for the whites. For an emergency job a 5 per cent solution of oxalic acid can be used for the whites, but this rapidly corrodes the pen.

Blueprints are made commercially in continuous operation from rolls of the sensitized paper which is carried, together with the drawings in contact, on an endless belt around a glass cylinder which is lighted from within.

As the drawings are likely to be larger than available printing frames, occasional work is done by placing the drawing and the sensitized paper under a sheet of plate glass on a drawing board and exposing to the sun.

When printing from negatives, the paper should, of course, be placed in contact with the emulsion side of the negative. The range of tones of a blueprint is so short that except for special effects it is not suitable for anything but line negatives, but very handsome effects are sometimes obtained by using it for pictures of suitable subject matter. There is a marked falling off in the depth of the image when washing the print, and this should be taken into account when printing.

It is sometimes difficult to get ferroprussiate paper in quantities small enough for amateur requirements, but the worker may easily prepare the sensitizer for his own use either upon paper or cotton or linen fabrics. It is painted on to paper in subdued light, while the fabrics are sensitized by immersion. The paper or fabric is stretched upon a line to dry in a room from which daylight is excluded. The sensitizing solution should be prepared immediately before use as it deteriorates rapidly. Printing is identical for either paper or fabrics, but the fabric, after washing, should be ironed flat while still slightly damp.

FERROPRUSSATE SENSITIZING SOLUTION

Solution A

Ferric ammonium citrate (red)	4 oz., 170 gr.	250 g
Water	16 oz.	1000 cc

Filter after solution is complete.

Solution B

Potassium ferricyanide	3 oz., 224 gr.	200 g
Water	16 oz.	1000 cc

Filter before use.

The ferricyanide must be in perfectly clear ruby-red crystals, and should be freed from any adherent yellow powder. To do this, allow a little more in weighing out, and place the crystals in a flask; pour in some distilled water, shake, pour off the water, and repeat this operation; then add the water for the solution, and heat until dissolved. Mix the two solutions in equal volumes and filter. Either float the paper on the solution for 3 minutes, or paint on the solution freely with a broad flat brush, and dry as quickly as possible, preferably by heat.

A much more sensitive paper is obtained by using the green ammonio-citrate of iron; then the solutions should be:

Solution A

Ferric ammonium citrate (green) ..	2 oz., 85 gr.	125 g
Water	8 oz.	500 cc

Filter and add:

Solution B

Potassium ferricyanide	346 gr.	45 g
Water	8 oz.	500 cc

Filter before use.

Mix equal parts of the two solutions and coat paper as above. Brighter prints are obtained by the addition of 0.5 per cent of oxalic acid to the above; the paper keeps better if 0.05 per cent of potassium bichromate is added.

The use of sodium or ammonium ferric oxalate gives greater speed than the above, but the paper does not keep so well. The sensitizer should then be:

Potassium ferricyanide	2 oz., 146 gr.	133 g
Ferric ammonium citrate (red) ...	2 oz., 402 gr.	166 g
Sodium or ammonium ferric oxalate	253 gr.	33 g
Water	16 oz.	1000 cc

All these solutions are sensitive to light.

Other iron salts may also be used, for instance:

Solution A

Sodium or ammonium ferric oxalate	4 oz., 170 gr.	250 g
Water	16 oz.	1000 cc

Solution B

Potassium ferricyanide	4 oz., 170 gr.	250 g
Water	16 oz.	1000 cc

Filter both solutions, mix, and again filter.

Or the following may be used:

Solution A

Tartaric acid	3 oz., 62 gr.	180 g
Ferric chloride (anhydrous)	1 oz., 85 gr.	68 g
Ammonia	q.s.	q.s.
Water	16 oz.	1000 cc

Dissolve the acid in three-quarters of the water, then add the iron, and, when dissolved, add sufficient ammonia to neutralize the acid, about $2\frac{1}{2}$ ounces (175 cc) being required; excess of ammonia must be avoided. Filter, and add to:

Solution B

Potassium ferricyanide	3 oz., 354 gr.	217 g
Water	16 oz.	1000 cc

Mix the two solutions. This gives greater sensitiveness, but the prepared papers do not keep so well as the others.

It is important that the paper base should be free from wood pulp, preferably sized with starch, and with a hard surface. It has been suggested to add white dextrine to the sensitizer, but this lowers the keeping quality. Coat the paper with a flat brush or swab of cotton. If pins are used to hold the paper they should be of stainless steel. Printing is slow and the paper should be exposed to sunlight, electric arc, or mercury-vapor light until the ground, corresponding to the whites of the negative or plan, appears a dark olive-green.

The print is then cleared by thorough washing in running water, and the lines should appear white on a deep blue background. With stale paper or with excess of or impure ferricyanide, the lines will appear more or less tinted. With underprinting the color is more or less pale, but by somewhat prolonging the washing, the lines may clear up.

A much more stable and contrasty image is obtained if the print is developed with a 0.2 per cent solution of potassium ferricyanide, and well washed for 4 or 5 minutes.

Toning.—Numerous methods have been suggested for toning blueprints, but, as a rule, the results are extremely unsatisfactory. Immerse the dry print in:

Ammonia, sp. gr. 0.897	96 minims	12.5 cc
Water	16 oz.	1000 cc

As soon as the blue color disappears, wash for a few minutes, and then immerse in a 2 per cent solution of tannin; this gives a blackish color, but the outlines may become blurred from spreading of the color into the whites. Or the print may be well washed in distilled water, and bleached in yellow light in:

Silver nitrate	154 gr.	20 g
Water	16 oz.	1000 cc

Wash with distilled water, and fume with ammonia, expose to light, and develop with ferrous oxalate; then wash thoroughly.

Lantern Slides.—The blueprint process may be used for making lantern slides or transparencies, although, naturally the color is suitable for but few subjects and the range of tones is short, but it is capable of giving some very striking effects in the rendition of snow, water, or night scenes. The sensitizing solution is rather weaker than used for paper:

SENSITIZER FOR LANTERN SLIDES

Solution A

Ferric ammonium citrate (green) ..	4 oz., 85 gr.	250 g
Water	16 oz.	1000 cc

Solution B

Potassium ferricyanide	1½ oz.	100 g
Water	16 oz.	1000 cc

Mix in equal volumes and filter. Gelatinized glass (fixed out dry plates may be used) should be immersed for 5 minutes, and rapidly dried. The sensitizer will not keep when mixed. The plates should be exposed like the paper, and washed in the same way.

CYANATYPE OR GUM-IRON PROCESS.—This process, originally patented by Pellet in 1878, gives the reverse of the ordinary blueprint, that is, the lines are blue on a white ground, in reality producing a positive from a positive. The paper does not keep well. It is faster than most blueprint papers and should be handled only in a very weak light. The image is brought out by development, being only slightly visible as bright yellow lines on a somewhat darker ground, which makes it difficult to judge the time of printing, but after a little practice judgment is soon formed. Several test strips under

India ink lines of the same density as the drawing that is being copied are sometimes simultaneously printed and developed one at a time as printing proceeds, to get an idea of the time needed.

As recommended by Pizzighelli, the sensitizer is prepared in three stock solutions:

GUM-IRON SENSITIZER

<i>Solution A</i>		
Gum arabic	3½ oz.	200 g
Water	16 oz.	1000 cc
<i>Solution B</i>		
Ammonio-citrate of iron (red)	8 oz., 340 gr.	500 g
Water	16 oz.	1000 cc
<i>Solution C</i>		
Ferric chloride	8 oz., 340 gr.	500 g
Water	16 oz.	1000 cc

These solutions will keep indefinitely in the dark with the exception of solution A which becomes acid in about a week. For use take: A solution, 200 parts; B solution, 80 parts; C solution, 50 parts. It is important to adhere to this order, for, if solution A be added to solution C, the mixture becomes lumpy and useless. The mixture is at first thin and fluid, but soon becomes more viscous, and in a few hours cloudy and of the consistency of soft butter. It should be used in this condition and will keep in the dark for several days.

Haugk recommended the following:

Gum arabic solution, 1 to 5	300-350 parts
Ammonium ferric oxalate solution, 6 to 10	100 parts
Ferric chloride solution, 1 to 2	20-30 parts

Float the paper on this mixture.

Another excellent formula suggested by Waterhouse is:

<i>Solution A</i>		
Gum arabic	6 oz.	170 g
Water	22 oz.	650 cc
<i>Solution B</i>		
Tartaric acid	1 oz., 180 gr.	40 g
Water	5 oz.	150 cc
<i>Solution C</i>		
Ferric chloride solution, sp. gr. 1.453 ..	3½-4½ oz.	100-120 g

Filter the gum solution through a sponge or pad of cotton, and mix with the acid; then add the iron solution, which should be weighed, not measured, with constant stirring. Allow the mixture to stand in the dark for 24 hours, and add water to make the specific gravity 1.100.

Well-sized paper, preferably gelatin-sized, should be fastened by stainless

steel pins to a flat board, and the mixture applied not too thickly with a flat brush. As soon as the brush begins to drag, the coating should be evened out with a round brush with circular strokes. This operation should be performed by artificial light, and the paper rapidly dried in the dark. The paper should be kept under pressure. The exposure will be from 15 to 40 seconds in the sun, or proportionately longer in diffused light, under a drawing; the image is seen in a bright yellow color on a darker ground.

Development is effected with a 20 per cent solution of potassium ferrocyanide; the paper may be pinned to a board, and a very soft brush, charged with the solution, passed over the surface, care being taken not to rub up the image. Or the edges of the paper may be turned back to the height of about an inch and the print floated, face down, on the solution. The edges are turned up to prevent any solution touching the back of the print, which would cause blue stains.

After development the print should be washed with a spray or in running water for 3 or 4 minutes, immersed in a 10 per cent solution of hydrochloric acid, for a minute or two, then transferred to another bath of the same composition for 4 or 5 minutes and then washed for a few minutes, and dried.

Corrections can be made with a solution of potassium oxalate, about 15 per cent, thickened if necessary with gum arabic.

FERROGALLIC PROCESS.— This is sometimes known as Colas's process. It gives black lines on a white ground, when printed under a drawing. The sensitizer is a mixture of ferric chloride or sulphate, and tartaric acid, thickened with gum, or gelatin:

Ferric chloride	480 gr.	50 g
Ferric sulphate (basic)	240 gr.	25 g
Tartaric acid	432 gr.	45 g
Water	10 oz.	500 cc

Dissolve and add:

Gelatin	240 gr.	25 g
Water	5 oz.	250 cc

Soak the gelatin in the water for 30 minutes and melt with heat. Filter the mixture through fine linen.

Or the following may be used:

Gum arabic	1 oz., 330 gr.	100 g
Ferric chloride	5 oz., 330 gr.	328 g
Tartaric acid	3 oz., 388 gr.	220 g
Ferric sulphate (basic)	3 oz., 388 gr.	220 g
Water	16 oz.	1000 cc

Dissolve in the above order and filter.

The following (Fisch) is suitable only for heavily sized or gelatinized papers:

Ferric chloride	1 oz., 330 gr.	100 g
Water	8 oz.	500 cc

Dissolve and add:

Tartaric acid	230 gr.	30 g
Water	8 oz.	500 cc

Or the following (Shawcross) may be used for any paper:

Gelatin	2 oz., 177 gr.	137 g
Ferric sulphate (basic)	422 gr.	55 g
Sodium chloride	1 oz., 231 gr.	87 g
Tartaric acid	130 gr.	17 g
Ferric chloride	2 oz., 177 gr.	137 g
Water	16 oz.	1000 cc

The solutions should be applied with a broad, flat brush or pad by artificial light, and rapidly dried. The paper will keep for 2 or 3 weeks.

Exposure under a drawing will take about 10 minutes in sunlight, or until the lines appear yellow on a white ground.

The developer consists of gallic and oxalic acids.

Gallic acid	46 gr.	6 g
Oxalic acid	7.7 gr.	1 g
Water	16 oz.	1000 cc

Or the following may be used:

Gallic acid	96 gr.	12.5 g
Alum	96 gr.	12.5 g
Water	16 oz.	1000 cc

The image should become black in from 3 to 5 minutes. The print may be completely immersed in the developer or floated on its surface. As soon as the image is intense enough, wash with repeated changes of water, gently blot off the surface water, and hang up to dry in a warm place. The blotting is important, as otherwise the lines tend to spread when drying. It should be noted that the ferric sulphate used in this process is the basic variety, also known as subsulphate, or Monsell's salt.

TRUE-TO-SCALE PROCESS. — This is a cheap and ready process for obtaining about twenty-five pulls in printer's ink from line drawings, etc. A good black original gives best results. Ferroprussiate or cyanotype paper should be exposed under the plan or drawing, and without development laid down on a "graph" or jelly, gently rubbed into contact, and immediately stripped. The jelly is now rolled over with printer's ink with a composition roller. The

ink adheres only to the lines. A piece of paper is now laid on the jelly and rolled over lightly with a light roller, and on lifting, the impression will be found on the paper. Inking must be done before each pull. The jelly can be made as follows:

Glue	8 oz., 340 gr.	500 g
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Allow to soak for some hours, melt with heat, and add:

Gelatin	480 gr.	62.5 g
Water to make	16 oz.	1000 cc

Soak, melt by heat, and add:

Ferrous sulphate	240 gr.	31.5 g
Glycerin	240 minims	31.5 cc

Strain, and cast into flat tins.

Another formula is as follows:

Gelatin	1 lb.	450 g
Water	90 oz.	2550 cc
Size powder	1 lb.	450 g
Iron alum	1½ oz.	42 g
Water	20 oz.	560 cc

Dissolve the gelatin in the water; then add the size powder. Dissolve the alum in the water, and add to the gelatin-glue solution gradually, stirring all the time. Pour into tins or on a slab. After use it can be remelted and used again, but a little fresh jelly should always be added.

Still another formula is:

Gelatin	2 oz., 353 gr.	160 g
Glycerin	115 minims	15 cc
Ox-gall	192 gr.	25 g
Ferrous sulphate	15.4 gr.	2 g
Water to make	16 oz.	1000 cc

Soak the gelatin in water, melt, add the other ingredients, and, finally, the iron salt dissolved in a little water. Cast on zinc which has been roughened with emery to cause it to adhere well. The coating should be 1/12 inch (2 mm) thick.

PLAYERTYPE is a method of copying printed matter invented by J. H. Player, in which a sheet of sensitive paper, bromide or chloride, is placed face down on the printed matter, pressed into contact and exposed through the back. On development, a negative copy is obtained. The slower papers are more suitable; the paper should be pressed into contact by a sheet of plate glass, and the latter covered with a yellow filter which can be made by immersing fixed-out dry plates in a 2 per cent solution of tartrazin. The

exposure varies from 30 seconds to 2 minutes, according to the sensitiveness of the paper and the strength of the light. The developer should be preferably hydroquinone well restrained with bromide, as generally used for line work. Printing-out paper may be used in the same way.

Another formula suggested by Albert is:

Albumen	460 minims	60 cc
Fish glue	307 minims	40 cc
Ammonium bichromate	346 gr.	45 g
Water	16 oz.	1000 cc

Still another formula is:

Fish glue	288 minims	37.5 cc
Ammonium bichromate	23 gr.	3 g
Grape sugar	25 gr.	3.25 g
Water	16 oz.	1000 cc

Dissolve the sugar in about one-quarter of the water before adding the other ingredients. Glass should be coated with this solution on a whirler and exposure made by a Mazda lamp at a constant distance, the glass being placed with the coated side down on the drawing. Development is effected with hot water, and the print can then be stained up with a solution of a dye, such as chrysoidin, water-soluble nigrosin, or by immersion in a 4 per cent solution of potassium permanganate, which gives a deep brown image of manganese dioxide.

COBALT-IRON PRINTING (Burian). — This process seems more suitable for line drawings than prints from ordinary photographic negatives.

Oxalic acid	61.5 gr.	8 g
Water	230 minims	30 cc

Heat until dissolved and add:

Ammonium oxalate (neutral)	184 gr.	24 g
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When dissolved add:

Cobalt carbonate	61.5 gr.	8 g
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Effervescence takes place, and the mixture should be digested until it turns red. The cobalt carbonate can be made by adding 299.5 grains (39 g) crystallized sodium carbonate to 123 grains (16 g) of crystallized cobalt chloride, and washing and drying the precipitate. To the above red liquid, cooled down to 95° F. (35° C.), add:

Lead peroxide	38.5 gr.	5 g
Glacial acetic acid	23 minims	3 cc

On shaking, the solution turns a deep green. From this point all further operations must be conducted by yellow light.

Add to the previous solution:

Lead peroxide	38.5 gr.	5 g
Glacial acetic acid	23 minims	3 cc

Pour the solution out into a flat dish, and allow to evaporate until crystals form and it is dry. Add 77 minims (10 cc) of water, filter, and make the bulk up to 16 ounces (1000 cc). The iron salt is obtained by mixing 154 grains (20 g) of ferric sulphate with ammonia, washing the precipitate, and adding 275.5 grains (36 g) of acid ammonium oxalate. This can be made by adding 230 minims (30 cc) of ammonia to 768 grains (100 g) of oxalic acid, gently heating, adding more ammonia until the solution smells distinctly of ammonia, then heating to drive off excess of ammonia, adding 768 grains (100 g) of oxalic acid, heating until dissolved, and allowing to crystallize.

The actual sensitizing solution is made by mixing 2 parts of the cobalt solution with 1 part of the iron. Paint on the paper with a brush and dry rapidly; the paper should be a green color. Exposure may be to daylight or an arc, and the image should show a bright yellow on the green ground. Development is effected in a 1 per cent solution of potassium ferricyanide until the whites appear white; then briefly wash and immerse in 1 per cent hydrochloric acid; again wash and immerse in a 1 to 400 solution of sodium sulphide until the paper turns gray; then wash until white. The sensitized paper will keep only about 6 hours. If the ordinary ferric oxalate is used, the process is said to be suitable for ordinary negatives.

GREASY OR PRINTER'S INK PROCESS.—In this process the fact that a colloid is made insoluble by the action of light on the iron salts, and the capacity of the insoluble colloids for taking greasy ink, are employed. It was suggested by Fisch:

Gum arabic	5 oz., 263 gr.	320 g
Water	16 oz.	1000 cc

Dissolve and add:

Tartaric acid	1 oz., 103 gr.	70 g
Water	4 oz.	250 cc

Then add with constant stirring:

Ferric chloride solution, 45° Bé. ...	3 oz., 288 minims	225 cc
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Then add:

Manganese sulphate	77 gr.	10 g
Water	192 minims	25 cc

Allow to stand in the dark for several hours, and then filter through fine muslin. Coat the paper in the usual way, and dry at 95° to 113° F. (35° to 45° C.).

Another formula is the following:

Gum arabic	5 oz., 308 gr.	325 g
Water	16 oz.	1000 cc

Dissolve and add:

Tartaric acid	1 oz., 138 gr.	75 g
or Citric acid	5 oz., 116 gr.	300 g

Then add, with constant stirring:

Ferric sulphate	200 gr.	26 g
or Ferric nitrate	7 oz.	400 g

And add in the same way:

Uranium nitrate	46 gr.	6 g
or Uranium chloride	3 oz., 224 gr.	200 g

Finally, add:

Ferric chloride solution, sp. gr. 1.453 ...	3 oz., 172 minims	210 cc
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Filter through muslin and coat upon well-sized paper. The exposure will be from 3 to 6 minutes in sunlight. Place the print face up on a sheet of zinc or glass, and with a roller lightly charged with printer's ink roll up the surface until uniformly gray. Immerse the inked print in cold water, transfer to a metal or glass plate supported at an angle, and allow a spray or stream of water to play over the surface. With a pad of absorbent cotton gently rub the print. The exposed parts will be gradually dissolved, leaving only the inked parts.

KALLITYPE.—Unlike the other iron processes which have been mentioned, kallotype is a very beautiful medium for presenting general pictorial effects. A suitable paper is coated with iron salt in solution and printed by contact in sunlight or under strong artificial light, which gives a faint image which is developed to full strength in a bath of silver nitrate. The print is then fixed in weak hypo for 3 to 5 minutes and washed for 30 minutes in running water. There has been considerable criticism of this process on account of alleged instability of the prints but it seems that in every instance this can be traced back to lack of fixation or insufficient fixation.

Among the many formulas which have been worked out for this process, that of James Thompson in 1904 seems to have become standard.

KALLITYPE SENSITIZER

Distilled water	10 oz.	300 cc
Citrate of iron and ammonia (brown scales)	320 gr.	21 g
Ferric oxalate	160 gr.	10.5 g
Potassium oxalate	330 gr.	21.7 g
Copper chloride	40 gr.	2.6 g
Citric acid	40 gr.	2.6 g
Silver nitrate	100 gr.	6.5 g
Oxalic acid	100 gr.	6.5 g
Gum arabic	100 gr.	6.5 g
Potassium bichromate solution 20 grains to the ounce (1.3 g to 30 cc) as required.		

Five to 10 drops per ounce (30 cc) is an average amount of the potassium bichromate solution to be used with average negatives. An increased amount of the bichromate increases the contrast of the print.

The solution should be mixed in an amber colored bottle, adding the chemicals in the order given, without agitation, other than turning the bottle upside-down once or twice. Store in a dark place for 24 hours and then filter through absorbent cotton, wringing the cotton out to obtain all of the sensitizing solution while excluding any gritty particles.

Any good writing paper may be used for kallotype prints. Softer papers will have to be sized with arrowroot or gelatin size. Apply the sensitizer smoothly to the paper with a rubberset camel's-hair brush or with a Blanchard brush. When surface dry, complete the drying by heating, to keep the sensitizer as much as possible upon the surface of the paper.

Print by inspection until the shadows appear in a deep yellow color. Disregard the highlights and halftones as these will not show at all upon a normal print.

STOCK SOLUTION KALLITYPE DEVELOPER

Distilled water	10 oz.	300 cc
Silver nitrate	400 gr.	260 g
Citric acid (crystal)	100 gr.	6.5 g
Oxalic acid	100 gr.	6.5 g

For use take 1 part stock solution to 7 parts water. Immerse the print face down in the developer and immediately turn over and break any air bells that may be adhering to it. Development will usually take about 1 minute, but keep the print in the developer until it is completely cleared and the full tones appear.

Rinse thoroughly and fix for 3 to 5 minutes in a very weak hypo bath compounded as follows:

Water	10 oz.	300 cc
Hypo	15 gr.	1 g

Wash thoroughly.

PLATINUM.—Prints in pure metallic platinum have great richness in the blacks, a long scale of gradations, and absolute permanence. The process is based upon the light sensitiveness of iron salts which are used with the platinum. A platinum salt is reduced, in the presence of a suitable developer, by the ferrous oxalate to which ferric oxalate in the emulsion has been reduced by the action of light.

The action of light upon a platinum salt was observed by Gehlen in 1804, and commented upon by Herschel in 1832. The first workable printing process was patented by William Willis in 1873 and subsequent years, and commercially coated paper was available until 1937, at which time the process was taken from the market, having been almost entirely superseded by other processes which were less expensive and which did not require the large negatives necessary for contact printing. Paper can be coated with the platinum emulsion by hand if the results warrant the expense.

The Paper.—Any paper, not too highly glazed, which is strong enough to withstand soaking for an hour or two in water, is suitable for platinum. The usual choice is a drawing paper or a vellum on account of their beauty and permanence. Most papers do not need to be sized, but it is advisable with soft papers. Soak up 80 grains of hard photographic gelatin in 4 ounces of water, melt in a double boiler, and apply to the paper with a sponge while it is still hot, rubbing it well into the pores of the paper. A thin paste of laundry starch may be used instead of the gelatin.

Sensitizing.—The following solutions, given by Paul L. Anderson, should always be made up with distilled water, which may be heated to 120° F. for convenience in dissolving the chemicals, but the solutions should always be used at room temperature.

Solution No. 1

Water	2 oz.	59 cc
Oxalic acid	16 gr.	1 g
Ferric oxalate	240 gr.	15.5 g

Solution No. 2

Water	2 oz.	59 cc
Oxalic acid	16 gr.	1 g
Ferric oxalate	240 gr.	15.5 g
Potassium chlorate	0.4 gr.	0.026 g

Solution No. 3

Water	2 oz., 3 drams	70 cc
Potassium chloroplatinite	219 gr.	14.2 g

These stock solutions, which keep indefinitely if stored in the dark, are mixed in varying proportions to give different degrees of contrast. The formulas are given in parts, which in practice will usually be drops, which are most convenient in measuring such small quantities as will be used because the working solution should be mixed only at the time of use. The minimum amount of sensitizer with which an 8 by 10 inch sheet can be coated is about

46 drops. This should be doubled and allowed to soak in if the richest blacks are desired. With hard papers on which it is difficult to handle the larger volume of solution, one minimum coating may be applied and allowed to dry, and then another coating applied over it. Or multiple printing may be resorted to, re-sensitizing the developed print and printing again.

WORKING SOLUTIONS OF SENSITIZER

<i>For very soft prints</i>		<i>For average prints</i>	
Solution 1	22 parts	Solution 1	14 parts
Solution 2	0 parts	Solution 2	8 parts
Solution 3	24 parts	Solution 3	24 parts
<i>For soft prints</i>		<i>For strong prints</i>	
Solution 1	18 parts	Solution 1	10 parts
Solution 2	4 parts	Solution 2	12 parts
Solution 3	24 parts	Solution 3	24 parts
<i>For extreme contrast</i>			
Solution 1	0 parts		
Solution 2	22 parts		
Solution 3	24 parts		

The paper is not sensitive to light until it is dry, so it can be coated in ordinary light. Pin or clip the paper horizontally on a firm support and pour the sensitizer on to it in a pool and spread it quickly with a brush, alternating the brush strokes at right angles, and continue the brushing until the paper is surface dry, when it should be hung up in the dark to complete the drying, which will take about 5 or 10 minutes.

The sensitized paper may be printed as soon as it is dry, or it may be kept with suitable precautions against the effect of dampness, up to about 3 months. It should be kept in a glass or metal container sealed with surgeon's tape, with a preservative made of a small roll of asbestos which has been soaked in a saturated solution of calcium chloride, then desiccated over a stove and wrapped in cotton and a thin, porous paper.

Printing.—Printing is done in sunlight, or with arc light, and the time depends upon the density of the negative, strength of the sunlight, or strength and nearness of the arc. For a general idea of the time, it will probably be between 3 and 10 minutes at 4 feet from an arc light. The image prints out in a light brown color, which is sufficient indication to the worker after a little practice in judging the depth.

If the print is not to be developed at once after printing, it should be returned to the container, as it readily absorbs moisture from the air, and this will result in degraded highlights.

Developing.—The developer keeps indefinitely, and improves with age, being kept up to volume by the addition of fresh developer to the old, which is decanted from the sludge that is likely to form in the bottom of the bottle.

PLATINUM DEVELOPER

<i>For cold blacks</i>		
Water (120° F.)	48 oz.	682 cc
Potassium oxalate	9 oz.	255 g
Monobasic potassium phosphate	3 oz.	85 g
<i>For neutral blacks</i>		
Water (120° F.)	48 oz.	682 cc
Potassium oxalate	1 lb.	454 g
<i>For warm tones</i>		
Water (120° F.)	48 oz.	682 cc
Potassium oxalate	1 lb.	454 g
Mercuric chloride	q.s.	q.s.

The exact amount of mercuric chloride depends upon the worker's preference in the warmth of color. An average amount to start with would be 60 grains (4 g).

Development is done at any ordinary room temperature, between 60° and 80° F. Break any air bubbles that may form on the print, and carry development to completion. There is no danger of overdevelopment as the action will stop automatically and it cannot be forced further.

The developer may be used either hot or cold. Hot developer (up to 150° F.) gives warmer tones and decreases contrast.

Clearing. — The standard treatment is to give the print, following development, three successive baths of 5 minutes each in a 1 to 60 solution of hydrochloric acid, followed by 20 minutes washing in running water. Weaker solutions of the acid are sometimes recommended because they give warmer prints, but such prints are likely to darken with age on account of imperfect elimination of the iron salts in the weaker bath. If the iron salts are completely eliminated, as they will be in the 1 to 60 bath, the print consists of only pure metallic platinum and is absolutely permanent.

The print may be dried between blotters, before a fan, or by heat.

Multiple Printing. — Depth can be added to the shadows of a platinum print, and the contrasts increased, by multiple printing. The print is sensitized as though it were plain paper. When dry, the negative is registered upon it and printing, developing, and clearing proceed as in the usual process. This printing may be timed for the full scale of the negative, or only for the shadows. Any number of additional printings may be given.

GUM PLATINUM. — A printing in gum, over the platinum, is sometimes used to give added strength to the shadows. The print must be sized before the gum coating is applied. The negative can be registered to the platinum print by transmitted light. The technique is the same as for regular gum printing (see page 225). Beautiful effects are obtained in this way, but the sheen imparted by the gum gives a quite different effect from the characteristic mat surface of the straight platinum.

PALLADIUM has been offered as a substitute for platinum, giving very similar effects at much less cost. The tones are likely to be warmer than those of platinum. The process is identical with platinum except that the third stock solution of the sensitizer contains sodium chloropalladite instead of potassium chloroplatinite.

STOCK SOLUTION NO. 3

(For Palladium)

Water	2 oz., 3 drams	70 cc
Sodium chloropalladite	156 gr.	10 g

Palladium is much less sensitive than platinum to potassium chlorate, which is used in increased concentration in the sensitizing bath to give added contrast to platinum paper (stock solution No. 2, under *Platinum*), but the contrast can be greatly increased by longer printing under a weaker light.

CHAPTER XIV

OIL, BROMOIL, AND TRANSFER

These processes depend upon the general principle that oil and water will not mix, and specifically upon the fact that a wet surface will repel a greasy ink. This principle was used by A. Poitevin in 1855 for photomechanical processes like collotype and lithography, where ink was applied by a roller to a bichromated gelatin surface that had been printed under a negative and then swollen in water. The bichromated gelatin was rendered insoluble in direct proportion as it had been acted upon by the light through the negative. When it was placed in water, the gelatin that had been protected by the heavy deposit representing the highlights of the negative would swell up and hold water readily, while the shadows would be insoluble and remain dry, and the halftones would take up an amount of water proportionate to their darkness. When the ink was applied, the different parts of the negative would accept the ink in proportion to their wetness, and the original image would reappear in ink.

In 1904 G. E. H. Rawlins introduced a modification called the *Oil* process, by which the ink was applied selectively by a brush, allowing great control of the result. The *Bromoil* process, as worked out by E. J. Wall and C. Welborne Piper in 1907, is based upon the discovery by Howard Farmer in 1889 that the gelatin under a silver image becomes insoluble when immersed in a solution of bichromate without the action of light. This enables the making of prints similar to oil prints direct from a bromide enlargement without the necessity for a large negative. The *Transfer* process, devised by R. Demarchy in 1911, removes the image from the gelatin base of either an oil or a bromoil print and transfers it to a plain paper.

OIL PRINTING.—Oil is printed by contact under a negative upon a paper coated with gelatin. Any paper can be prepared with several coatings of gelatin, but the papers specially prepared by the Autotype Company of London, or one of their double-transfer papers for the carbon process, are usually preferred on account of the evenness of the coatings. Photographic paper that has been specially prepared in manufacture for the bromoil process may be used for oil by fixing out the silver emulsion in a bath of plain hypo and then washing and drying it. The paper should be enough larger than the

negative to allow a safe edge of about $\frac{3}{4}$ inch all around the subject, for convenience in inking.

Sensitizing.—The paper is sensitized by immersion in a 3 per cent solution of potassium bichromate for about 3 minutes, at a temperature between 65° and 70° F. It is dried by hanging it by one corner in a room of the same temperature. When wet, the sensitized paper is not sensitive to light, but it becomes so upon drying, so it should be dried in a darkroom. Drying will be complete in about 2 hours unless the air is damp. Paper dried slowly in damp air will never make a good print. An alternate method of sensitizing, to avoid trouble in damp weather, is to use a spirit sensitizer.

SPIRIT SENSITIZER

Ammonium bichromate 6 per cent	1 part
Alcohol	2 parts

The paper is pinned to a board and the sensitizer brushed on with a flat brush, a Blanchard brush being most convenient for this work. The paper will be dry and ready for printing in about 15 minutes. After sensitizing, the paper may be kept for a few days in a dry place, well protected from light, but it is likely to deteriorate quite soon, and for best and surest results it should be printed within 24 hours.

Printing.—The paper is printed in daylight, either diffused light or sunlight, the latter tending to give more contrasty prints. Arc lights or sun lamps may be used for printing with correspondingly longer exposures. Exposure times can be determined by the use of an actinometer, but the image is so plainly visible on the bichromate-stained paper that the depth of printing is best judged by inspection. Print until highlight details are plainly but very faintly visible. As soon as printing is complete, wash the paper in several changes of water until the bichromate stain is discharged. It may be necessary to raise the temperature of the water gradually up to about 90° F. to do this, but the washing should start at room temperature and be raised gradually, as any sudden change in temperature is likely to affect the gelatin in such a way as to make inking difficult.

After washing, the paper may be used immediately, or it can be dried and kept almost indefinitely, so that it is perfectly feasible to print at any opportunity and store the paper for future inking. To prepare the paper for use, it is soaked for about 1 hour in water at a temperature of about 70° F., to swell the gelatin. If it is not then in condition for inking, the temperature may be gradually raised to as high as 100° F., but this would indicate that the gelatin base used was not suitable for this process, and poor results and difficulties in inking would likely be encountered. The technique of swelling the gelatin and of inking is identical with that of bromoil which is given below, so it will not be repeated here.

BROMOIL.—The bromoil process has largely superseded oil because the print is made from a bromide enlargement, obviating the necessity for a large negative and for daylight printing, and because it gives a longer range of tones.

The Paper.—The prime requisite in a paper for bromoil is that the gelatin should be soft. While bromoil prints can be made by the expert upon almost any enlarging paper, papers whose gelatin has been hardened either in manufacture or in processing give rise to many difficulties which are avoided by using paper specially prepared for the process, which can be obtained upon order from some of the larger manufacturers. Ordinary papers vary greatly in the hardness of the gelatin, and some of them work quite well for bromoil. If the commercially prepared paper is not available, any paper can be tested for its suitability for this process by soaking a scrap of it for 1 hour in water at about 85° F. If at the end of this time the gelatin has a distinctly swollen appearance, looks shiny and feels slimy to the touch, it may be used for bromoil with expectation of success. The emulsion should be rich in silver, and contain a certain amount of starch. Dead mat papers usually contain so much starch that they take the ink too readily. The proper amount of starch is usually found in the semi-mat papers, while glossy papers are deficient in starch and almost impossible to handle. Smooth papers work most easily, but rough papers often give more pleasing effects. Papers with a pronounced pattern may be used, but it must be remembered that the pattern will show more plainly in the bromoil print than in the bromide enlargement.

The Bromide Enlargement.—The bromide print should be so exposed that it can be developed to finality without attaining the blackest tones that the paper can render. This means a full exposure and development with a dilute developer. Full development is important, but heavy, black shadows are difficult to ink. Overexposed, muddy prints that have not been fully developed will never make a good bromoil. Shading, dodging, and spot-printing may be used in making the print if the result is allowed to develop automatically with the rest of the print, but manipulations during development are likely to lead to trouble. For compressing the scale, use the Sterry process (see page 169).

Many kinds of developer may be used to develop the print from which a bromoil is to be made, but an excess of carbonate should be avoided. If the carbonate exceeds 2½ per cent of the developing solution, it will harden the emulsion so that it will take the ink too readily. As amidol works without any carbonate, it is the developer most used for this process.

AMIDOL DEVELOPER

Water	30 oz.	887 cc
Sodium sulphite	1 oz.	28 g
Potassium bromide	10 gr.	0.6 g
Amidol	75 gr.	5 g

An acid amidol developer gives a very soft print with a long scale, and is preferred by many workers, especially for high key effects.

ACID AMIDOL

Water	30 oz.	887 cc
Sodium sulphite	2 oz.	56 g
Potassium metabisulphite	6 gr.	0.4 g
Potassium bromide	15 gr.	1 g
Amidol	35 gr.	2.3 g

Enough bromide must be used to prevent the slightest suspicion of fog. Fog so slight as to be scarcely noticeable upon the print, may cause a lot of trouble on the bromoil. For this reason darkroom lights should be carefully tested. Traces of iron also cause trouble in bromoils. Water should be filtered to remove from it any rust collected in the pipes. Glass, porcelain, or rubber trays are preferable because iron is likely to find its way into the developer from chipped or poorly enameled iron trays. If enameled iron trays are used, it is advisable to paint them with a chemical-proof varnish which is obtainable from most photographic dealers.

Prints developed in amidol must be thoroughly rinsed before fixing, to remove the oxidation products which are likely to locally harden the gelatin and cause dark patches in the bromoil.

Fix in a plain hypo bath, or one acidulated with potassium metabisulphite, or sodium bisulphite. Any bath containing alum or other hardening substance will absolutely prevent the selective hardening of the emulsion upon which the bromoil process depends.

ACID FIXING BATH

Water	32 oz.	1000 cc
Hypo	8 oz.	250 g
Potassium metabisulphite or sodium bisulphite	365 gr.	24 g

Thorough fixation is secured by 2 minutes' immersion with constant agitation in this bath, using fresh solution for each print, and this practice is better than longer immersion of several prints in the same bath. After washing, the prints may be bleached immediately, but it is preferable, especially in warm weather, to allow them to dry before performing the subsequent operations.

Bleaching.—The print, after fixing and washing, may be placed directly in the bleaching solution, but if, as is preferable, it has been allowed to dry, it should be soaked in water until limp and then drained before bleaching. As may be seen from the following tables, there is a wide choice of bleaching baths any one of which will simultaneously remove the silver image and harden the gelatin in proportion to the amount of silver originally deposited upon it, which is the action upon which the bromoil process depends.

BLEACHING BATHS

	1	2	3	4	5	6	7	8
Potassium bichromate	22.5	18.2	10	8	10.3	8	10	29.5
Potassium bromide	11.25	10	—	7	10.3	15	3	7
Potassium ferricyanide	11.25	10	20	10	2.3	10	3	59
Potash alum	45	36.4	10	0.5	—	40	10	—
Ammonium alum	—	—	—	—	20.5	—	—	—
Citric acid	11.25	10	—	1	—	—	—	—
Salt	—	—	53	—	—	—	—	—
Glacial acetic acid	—	—	7-14	—	—	—	—	—
Hydrochloric acid	—	—	—	—	3	15	1	—

1. Hewitt; 2. Rennie; 3. Weissmerel; 4. Schmidt; 5. Garner; 6. Rennie; 7. Rennie; 8. Quentin.

	1	2	3	4	5	6
Chromic acid	5	1.4	2.2	2	1-2	2
Potassium bromide	20	14	19.8	18	20	30
Cupric sulphate	—	28	33	30	30	18

1. Namias; 2. Smith; 3. Anon.; 4. Schrott; 5. Wurm-Reitmayer; 6. Duvivier.

	1	2	3	4	5	6	7	8	9	10	11	12
Cupric sulphate	20	12	—	40	43	40	22	30	9.2	10.4	11.5	10
Cupric bromide	—	—	50	—	—	—	—	—	—	—	—	—
Potassium bromide	10	8	—	40	43	20	20	30	9.2	10.4	11.5	10
Potassium bichromate ..	10	2	1	2	1.4	1	2	15	.8	1.2	—	0.8
Potash alum	—	—	—	—	—	—	—	10	—	—	—	—
Chrome alum	—	—	—	—	—	—	—	1.8	2.3	—	—	2
Sulphuric acid	—	—	—	—	—	—	—	0.5	0.6	0.6	0.6	0.6
Glacial acetic acid	—	—	—	—	—	—	—	40	—	—	—	—
Potassium chromate. ...	—	—	—	—	—	—	—	—	—	—	1.15	—

1. A. B. W.; 2. Mortimer; 3. Ermen; 4. Namias; 5. Seeman; 6. Brum de Canto; 7. Bendorf; 8. Weissmerel; 9. Featherstone; 10. Featherstone; 11. Gillin; 12. Wellington & Ward.

	1	2	3	4	5	6	7	8	9	10	11
Cupric sulphate	29	28	30	24	7.5	15	18	10	25	12.5	27
Potassium bromide	29	32	30	20	5	10	18	8	25	—	—
Potassium bichromate .	4.6	—	—	—	3.75	7	3	1	5	1.5	—
Ammonium bichromate	—	4	5	10	—	—	—	—	—	—	47
Hydrochloric acid	0.46	0.4	0.5	1.5	1	2	1	0.5	0.5	—	1
Sulphuric acid	—	—	—	—	—	—	—	—	—	0.5	—
Potash alum	—	—	—	—	—	—	—	—	0.5	—	—
Salt	—	—	—	—	—	—	—	—	—	69	13.5

1. Mayer; 2. Karpinski; 3. Tolokowsky; 4. Switkowski; 5. Birmingham Phot. Co.; 6. Rennie; 7. Mayer; 8. Namias; 9. Sturenburg; 10. Garner; 11. Switkowski.

The quantities of the ingredients given in the above tables (Mebes) are for a total volume of 1000 parts of solution.

If the print is bleached in any one of the first group of baths (which contain potassium ferricyanide), bleaching should be followed by a 5 minute treatment in a 5 per cent sulphuric acid bath.

Some typical working formulas from these different groups are:

DR. EMIL MAYER BLEACHER

Cupric sulphate, C.P.	230 gr.	30 g
Potassium bromide	230 gr.	30 g
Potassium bichromate	38 gr.	5 g
Hydrochloric acid, C.P.	23 minims	3 cc
Water to make	16 oz.	1000 cc

FLOYD VAIL BLEACHER

Cupric sulphate, 10 per cent solution	1 oz., 288 minims	100 cc
Potassium bromide, 10 per cent solution	1 oz., 288 minims	100 cc
Potassium bichromate, 10 per cent solution	56 minims	7.5 cc
Hydrochloric acid, C.P.	1½-4 minims	0.2-0.5 cc
Water	15 oz.	1000 cc

Use at a temperature of about 65° F. (18° C.). Time of bleaching should not be less than 3 minutes.

BARNET BLEACHER (Stock solution)

Cupric sulphate	½ oz.	25 g
Potassium bromide	½ oz.	25 g
Potassium bichromate	16 gr.	1.5 g
Glacial acetic acid	20 drops	32 drops
Water	20 oz.	1000 cc

Use 1 part of the above stock solution with 2 parts of water.

WELLINGTON AND WARD BLEACHER

Cupric sulphate	80 gr.	8.4 g
Sulphuric acid	5 drops	8 drops
Potassium bromide	80 gr.	8.4 g
Potassium bichromate	7 gr.	.74 g
Chrome alum	16 gr.	1.65 g
Water to make	20 oz.	1000 cc

CHROMIC ACID BLEACHER

Cupric sulphate, saturated solution	279 minims	35 cc
Potassium bromide, saturated solution	115 minims	15 cc
Chromic acid, 1 per cent solution	230 minims	30 cc
Water to make	16 oz.	1000 cc

The chromic acid bleacher is a favorite with many workers as it is easily made up from the stock solutions which keep indefinitely, and it gives unfailing results with most papers.

Bleaching may take from 5 to 30 minutes, depending upon the temperature and composition of the bath and upon the kind of paper and how it was developed. Baths should be compounded with great care to keep the proportions of the ingredients, although the amount of dilution may be increased as this affects only the time of bleaching. More concentrated solutions than those recommended above are likely to cause trouble. Prints should be

bleached until the silver image entirely disappears, leaving only a faint yellow-green image. If the silver image refuses to disappear entirely from the shadows, it indicates that they have been printed too deep. Passable bromoils may still be made from them, and if not too firmly set, they may disappear in the final acid hypo bath, or they may often be removed by a $2\frac{1}{2}$ per cent sulphuric acid bath.

After bleaching, the print is rinsed in several changes of water to discharge the yellow stain, and then immersed for 5 minutes in the sulphuric acid bath if that is necessary on account of having used ferricyanide in the bleacher, or because the silver image did not bleach completely. The sulphuric acid bath does no harm even if not specifically needed, and some workers use it habitually in a 1 per cent solution, increasing the concentration up to $2\frac{1}{2}$ or 5 per cent if any of the silver image remains or if ferricyanide has been used. The print is then washed for about 10 minutes to remove the sulphuric acid from the emulsion so that it will not contaminate the following fixing bath. Its elimination can be tested by tasting the print.

A final fixing is necessary to remove a latent secondary image that has been formed and might appear to the detriment of the pigmented image after several years. Five minutes in a 10 per cent hypo bath with $\frac{1}{2}$ per cent of potassium metabisulphite or sodium bisulphite will remove this image, after which the print should be washed and dried.

While all the operations from making the bromide print up to the production of the finished bromoil are sometimes done continuously, this puts a severe strain upon the emulsion and various troubles are likely to be induced. It is safer to allow the print to dry after the first fixing, and the drying after the second fixing is often so vital to the success of the process that it should never be omitted except in emergency, and then at the maker's risk. Bleached prints can be stored for a long time and inked up at convenience, even after several years.

Soaking.—The dried print must be soaked and allowed to absorb water in indirect proportion to the selective hardening action of the bleacher. The time of soaking will vary according to the temperature of the water and the nature and condition of the emulsion, and must be determined by inspection. When the water is blown away from the surface of the print, the image may be seen in some relief, but except with a paper whose characteristics are known, this is no indication of its condition, as the degree of swelling varies with different papers. The real test is by feeling. When the paper is in condition to receive the ink, the highlights have the slippery, slimy feeling characteristic of wet gelatin. This feeling is easily recognized once it has been learned.

For an unknown paper, soak for 15 minutes at 75° F. Remove it from the water and blow or mop the surface water away from a small area, preferably where a highlight adjoins a shadow, and note whether it feels in the con-

dition described. If not, raise the temperature about 10 degrees and soak for another 15 minutes and test again. Papers vary greatly in the temperature required to condition them, and once this has been learned they can be soaked up at that temperature with assurance of success if all conditions are standard, and the paper is not too old, in which case it will require a higher temperature. The temperature may be raised if necessary to about 115° and the swelling helped by the addition of a few drops of ammonia to the water, but beyond 115° or with the use of ammonia the emulsion becomes so tender that it must be inked up with great care lest the emulsion be broken and the print ruined. Most papers adapted to bromoil will swell at about 85°, although some of them may take up to an hour to do so, and the emulsion is much less liable to damage if it can be worked at a temperature no higher than that.

When soaking a print, it must be kept continuously under the water. Any part that projects above the surface of the water will not swell with the rest and will cause dark areas on the print, but it can be put back into the water and allowed to soak up evenly with the rest of the print. The print should be inserted into the water face up and weighted with tufts of absorbent cotton distributed over its surface, which will keep it under water without attention.

When removed from the water, the print must be freed from all surface moisture by wiping it with a viscose sponge or dabbing it with a lintless cloth. Linen is better than cotton for this purpose, and an often-laundered handkerchief is ideal for the purpose. Lint sticks to the fibers of the paper and shows up badly in inking. Hold the print slantwise to the light so that the surface of the paper can be plainly seen, and remove all the drops of water. The process depends upon the water *in* the gelatin. Any drops of water *on* it will repel the ink.

Inks and Brushes.—The inks specially prepared for bromoil by several manufacturers, in different colors and different degrees of hardness, are ideal for the purpose, and their use is advised at all times and especially for beginners. Hard lithographic ink and engravers' ink have much the same consistency, and are often used by experienced workers. Oil paint as supplied for artists is not homogeneous enough for this process. Linseed oil varnish without dryer is used for thinning ink, but the "medium" sold by the manufacturers of the inks is more convenient.

The brushes used for bromoil are a special pattern, cut "stag-foot" to facilitate the stippling motion by which the ink is applied. The standard brush is of fitch hair which gives a very fine and smooth deposit of ink. Bristle brushes give a little coarser effect and are preferred by many workers. They may be had in many sizes, but one about 2 inches in diameter and a smaller one about $\frac{1}{2}$ inch in diameter are sufficient for most needs.

The success of the work depends largely upon the condition of the brush. This means buying a good brush and keeping it in good condition. The brush will be ruined if ink is allowed to dry in it. At the close of work all

ink should be removed with benzol, which is highly inflammable, or with carbon tetrachloride which is equally efficient, and safe to use. The brush should then be washed with warm soap suds, rinsed in clean water, and hung with the bristles down, to dry. The brush should be kept in the waxed paper guard which is supplied with it, to keep it in shape.

Inking.— The print is placed upon a smooth support, like a sheet of plate glass, rubber, or heavy linoleum. If glass is used, a smooth, wet cloth should be placed between the glass and the print so that the print will adhere by suction. The cloth should be lintless, so that if the brush overruns the print it will not pick up lint from the cloth. The idea of the support is to hold the print firmly so that it will not slip when the brush is applied to it.

The ink is spread out thinly upon a sheet of glass, porcelain, or waxed paper and the brush charged by dabbling only the tips of the hairs upon it. The ink should be worked thoroughly and evenly all over the surface of the brush, and this is best done by working it, after it has been charged with ink, upon a clean surface of the palette. It is then tested by applying it to a clean sheet of paper. It should give an even deposit of ink, without blobs.

Ink is applied to the print by gentle pressure, setting the toe of the brush down upon the paper first. As the brush spreads out under pressure the rest of it will engage the paper and deposit ink if the print is in the right condition to receive it. Try it first on a place where a highlight comes next to a shadow, and if one accepts and the other rejects the ink, the work may proceed. Otherwise, the print is returned to the water for further conditioning. With a little practice the brush can be made to either deposit or remove ink, the latter by a hopping motion employing the heel of the brush. It is this manipulation of the ink with the brush that gives the worker the control of the process that enables him to alter values at will. In the straight process, without brush manipulation, the bromoil will accept the ink proportionately and build up an exact replica of the original bromide print.

When the print has dried down from exposure to the air so that it begins to accept the ink too freely, it should be returned to the water and soaked up again, and this process may be repeated as many times as is necessary until the print is completely inked. Any damage to the appearance of parts of the print already inked, caused by the re-soaking and swabbing off again, is easily repaired with a few strokes of the brush.

The pigmented image should be built up by repeated thin applications of ink, rather than by trying to put on a thick coating with one application. It is best to begin with a fairly hard ink and thin it only as necessary for smooth working.

When the print is inked it should be loosely pinned to a board and allowed to dry, which will take one or more days, depending upon the humidity of the atmosphere, the consistency of the ink, and how heavily the print has been pigmented.

Defatting.—After the print is thoroughly dry, it may be defatted, to give it a mat appearance, by immersing it for about 3 minutes in a tray of benzol, rocking the tray all the while. Prints upon which both hard and soft inks have been used sometimes present a spotty appearance which is removed by defatting, but always with a loss of brilliance which the oil imparts.

TRANSFER.—Oil or bromoil prints may be transferred from the gelatinized paper on which they are made, to any other kind of paper that the maker prefers. A good grade of water color paper is often used. Soft papers like those used for copper-plate printing usually absorb the ink too readily. If the paper is too hard, it can be made to work by spraying it with turpentine, which dries immediately and leaves the paper in condition.

The transfer process reverses the print, but this can be compensated for in the case of bromoils by making the bromide enlargement in reverse.

Hard ink transfers with difficulty, so that the print should be soaked up to such a degree that soft ink can be used. A bath containing 1 per cent ammonia may be used instead of the higher temperature and this is likely to leave the emulsion tougher and better able to withstand the pressure of the transfer. Ink transfers more readily from the highlights and halftones than from the shadows, which are likely to lack the richness of the original when transferred. To remedy this, several pulls in register are usually made, sometimes inking only the shadows and the parts that need strengthening, for the subsequent pulls after the first. Registration is easily secured by ruling lines in both directions across the back of the print and extending on to the transfer paper. These interrupted lines can be easily matched up for subsequent pulls.

The press used for transfer must be able to deliver considerable pressure and this can be secured only by rollers. Presses of the platen type are not satisfactory. An etcher's press is ideal. A press may be improvised from two metal rollers with trued surfaces which are operated by a crank. An adjustable space must be left between the rollers, and there must be means of setting the rollers together by strong springs.

The freshly-inked print is laid face down on the transfer paper which is placed upon a piece of thick, smooth cardboard. Several thicknesses of soft paper are put over the back of the bromoil and then another sheet of cardboard. This "pack" is run through the press first with just enough pressure to make the print adhere to the transfer paper. The pack is then run through several more times with increasing pressure each time. After about three trips through the press, the pack is opened and one corner of the bromoil carefully pried up from the transfer paper and inspected to see how much of the ink is transferring and to determine whether or not more pressure is needed.

Many transfers can be pulled from the original bleached bromoil print by successively re-inking it. When putting it away for future use all the remaining adhering ink should be cleaned off with a swab of soft cloth wet with carbon tetrachloride.

OLEOBROM.—This process is a variety of bromoil that was introduced by F. F. Renwick and F. J. Shepherd in 1930, in which the prints were inked by rollers instead of brushes. A special paper with very hard emulsion, and special inks were required. After bleaching and drying, the ink was first applied to the dry print by a roller. The uniformly blackened print was then further manipulated by rollers while under water, until the image appeared and was then lifted from the water, the surface dried, and development completed by further rolling.

OIOLOGRAPH.—This is a modification of the bromoil process, in which a plain gelatin paper is used. A good bromide print is soaked in water for 5 minutes, then squeegeed into contact with the gelatinized paper, which has been soaked for 2 to 2½ minutes at 60° F. in the following:

Potassium bichromate	84 gr.	11 g
Potassium ferricyanide	58 gr.	7.5 g
Potassium bisulphate	5 gr.	0.625 g
Potassium bromide	58 gr.	7.5 g
Chrome alum	11 gr.	1.6 g
Water	16 oz.	1000 cc

The print and the paper should be allowed to remain in contact under slight pressure for 20 minutes, then separated, and the print washed, when it can be redeveloped and used again. The gelatin-coated paper, after stripping, is placed in water at 90° F. for a few minutes; then a relief begins to show, and it can be inked up as usual. Either single or double transfer carbon paper may be used for the gelatinized paper.

CHAPTER XV

GUM-BICHRIMATE PRINTING

This process was invented and patented by Pouncy in 1858 but never came into popular favor until near the end of the nineteenth century, when it was revived by a group of workers including Ruouillé-Ladevèze, Demarchy, Maskell, and Puyo.

The process is based upon the fact that a bichromated and pigmented colloid becomes insoluble in proportion as it has been acted upon by light; specifically, under the different parts of a negative. It is essentially a short-scale process, but by multiple printing a scale of tones can be built up as long as, or longer than, that of any other process. It affords an unlimited choice in color and in the texture of the paper upon which the print is made, and in personal control of lines, tones, and masses.

THE PAPER.—Practically any kind of paper can be used but the choice usually runs to a fine linen or one of the drawing papers on account of their beauty and permanency. Smooth surfaced papers are used to render the finest detail, while rougher surfaces give the broad effects to which this process lends itself so beautifully. Tinted paper can sometimes be used to good advantage. In multiple printing the paper is subjected to many alternate processes of wetting and drying, and as far as possible a paper should be chosen which will stand this treatment without undue stretching or shrinking which cause difficulty in registration.

SIZING.—While some papers can be used without sizing, the majority need to be sized and in no case does it do any harm. A good size is made by soaking 1 ounce of gelatin in 10 ounces of water and then dissolving it by gentle heat in a double boiler. Add an equal volume of 1 per cent chrome alum and apply the mixture while it is still hot to the paper, rubbing it well into the pores with a small sponge, and allow it to dry. If the paper is very porous it will need a second coating of the size, as two thin coats are better than a heavy one.

A paper may be coated with plain gelatin and then with a 25 per cent solution of formaldehyde instead of using the chrome alum.

It is not necessary to use photographic gelatin as equally good results are secured by using the gelatin sold for cooking purposes.

The paper may also be sized with a fairly thick paste of laundry starch instead of the gelatin, and some workers prefer this method.

THE GUM.—Any colloid substance such as white of egg, glue, gelatin, or mucilage may be used for this process but pure gum arabic is the favorite

medium for most workers. This should be prepared some time in advance of use by suspending some of the pure "tears" of the gum arabic in a cheese-cloth bag in a jar containing about three times their volume of water. This will be dissolved after 2 or 3 days and it forms the stock solution of gum. A few drops of formaldehyde or carbolic acid, or a little bichloride of mercury, should be added as a preservative to prevent fermentation.

THE PIGMENT. — Pigment of any color, dry or moist, can be used, but it must be very finely ground to avoid granularity. The moist water colors as supplied in tubes for artists are ideal for the purpose and present many conveniences in operation. The pigment is very finely ground, it is available in any color, and any combination of colors can be made. The pigment is squeezed out of the tube in a continuous ribbon the length of which can be measured, which affords a much easier method than weighing for determining an exact amount, and makes it a simple matter to duplicate results.

THE SENSITIZER. — While ammonium bichromate is sometimes used in this process on account of its greater sensitivity to light, the usual sensitizer is a saturated solution of potassium bichromate. It is used in a saturated solution which would be about 10 per cent at ordinary working temperatures, but it is well to put 2 ounces of the potassium bichromate into 10 ounces of water which may be heated to speed up the solution. When it has cooled, there will be a residue in the bottom of the bottle proving that the solution which is decanted from the top is saturated.

THE COATING MIXTURE. — To secure different effects, the bichromate, the gum, and the pigment are mixed in various proportions which must be determined by the worker to suit his individual needs. An average procedure would be as follows:

MIXTURE FOR SHADOW COATING

Lampblack	4 in.	10 c
Gum	$\frac{1}{2}$ oz.	15 cc
Sensitizer	1 oz.	30 cc

MIXTURE FOR HALFTONE COATING

Lampblack	2 in.	5 c
Gum	$\frac{1}{2}$ oz.	15 cc
Sensitizer	1 oz.	30 cc

MIXTURE FOR HIGHLIGHT COATING

Lampblack	1 in.	2.5 cc
Gum	$\frac{1}{2}$ oz.	15 cc
Sensitizer	1 oz.	30 cc

The amount given is sufficient for several sheets of 11 by 14 inch paper, but the coating mixture is very inexpensive and it is well to have plenty on hand before commencing to coat.

The gum and the sensitizer should first be mixed and then the pigment thoroughly ground in with a mortar and pestle, being sure that the mixture is thoroughly homogeneous.

COATING THE PAPER requires a certain amount of manual dexterity which is easily attained with a little practice. The essential thing is to get the coating on to the paper as evenly as possible.

Pin the paper flat upon a drawing board, underlaying it with a piece of newspaper to receive the slop over the edges. Pour the mixture into a saucer so that it can be easily taken up with a wide brush. A flat hog-bristle brush or a camel's-hair mop, about 2 inches wide, are the favorites for this kind of work, but any brush with which a smooth wash can be laid may be used. A good quality of brush, preferably set in rubber, is an advantage because cheaper brushes shed bristles which are difficult to remove from the coating. Having the brush well charged with the mixture, press it out a little against the side of the dish so that the brush will be thoroughly charged but will not drip. Beginning at one edge of the paper, make a wide sweep clear across from side to side. Follow this with another sweep in the same direction slightly overlapping the first and continue until the whole printing area is covered. It is more convenient to have the paper larger than will be needed for the negative so that it will not be necessary to coat clear to the edges.

This roughly applied wash must be blended to even it up, and the work must be done quickly as it will begin to set within a minute. A fitch or badger brush, known as a "blender," is ideal for this purpose. Work the blender across the paths made by the wash and then at right angles, continuing until the mixture begins to get tacky and to cling to the brush, when work must be stopped or the coating will be ruined. The action of the blender must not be too vigorous. Heavy pressure is likely to stir up bubbles in the gum.

The coating mixture is not sensitive to light until it is dry, so all these operations can be carried out in ordinary room light, either daylight or artificial. If the drawing board is stood up in a dark corner of a room, face to the wall, where no direct light will strike it, it will dry safely within 1 or 2 hours, depending upon the humidity of the atmosphere. It may be printed as soon as it is dry, or it may be kept in the dark for several days before printing.

PRINTING. — Printing is done by contact, by daylight or carbon arc or other strong light sources. Direct sunlight is used by some workers and avoided by others. The action of direct sunlight, as well as of the carbon arc, is likely to produce more contrasty prints than are obtained by diffused light. Neon tubes and mercury vapor are sometimes used. No exact time can be given for the printing as it varies with the density of the negative, the amount of bichromate in the mixture, the amount and color of the pigment used, and with the results desired. Light colors print faster than dark ones and the blue end of the spectrum prints faster than the red. Browns contain so much red that they print very slowly. A visible image is formed when

printing and, especially with the lighter colored pigments, this is plain enough to serve as a guide to the experienced worker.

Negatives may be timed with an actinometer, which is almost a necessity when printing by daylight which varies greatly from moment to moment, unless the worker has acquired sufficient experience to judge the appearance of the printed image.

Actinometers are available commercially, but one may be made by cutting strips of thin writing paper, each one overlapping the preceding by $\frac{1}{2}$ inch or so. These are bound up in such form that when placed in the printing frame, the light comes through from one to ten thicknesses of the paper. These strips are then numbered with a pencil.

The negative is placed over a sheet of printing-out paper in a printing frame and the actinometer is placed over a similar sheet of printing-out paper in another frame. Both are exposed to the same light together and the image watched from time to time as it prints out under the negative. When this paper is printed deep enough to show good detail in the highlights, the time is about right for an average gum. This time will be shown on the printing-out paper under the actinometer in terms of the number of steps that are visible. The negative is now placed over the gum-sensitized paper and another sheet of printing-out paper put in the actinometer, and both are exposed to the same light. When the paper under the actinometer shows the predetermined tint, the gum may be considered printed. This gives only a general idea of the printing time required, but the timing can be figured quite accurately after one or two trials have been developed and the results noted.

DEVELOPING.—Developing consists of simply washing away the soluble gum in water. There is a continuing action of light in the coating after exposure has been stopped. As this amounts to increased exposure and is very difficult to allow for, it is best to develop as soon after printing as possible. For development, a print is placed in a tray of water at ordinary room temperature (65° to 75° F.). Leave it face up for a few minutes until it becomes limp, but taking care that the whole surface is under water, then turn it over and brush off any air bells that may have formed upon the back. Turn it over again and leave it unattended for an hour or so face down in the water and if it has been correctly exposed, it will develop automatically. If the image shows plainly in less than half an hour it has been underprinted. If it shows very quickly, nothing can be done to save the print and it is better to hold it under water and wash off all the pigment with a sponge. When dry it can be recoated. If the sponge action is very vigorous, it is best to size the paper again before recoating it.

If the paper has been overprinted and shows but little detail after an hour's soaking, detail may be brought out by gradually raising the temperature of the water to 100° or even 125° F. In extreme cases, a few drops of ammonia added to the water may secure results.

CONTROL.—Local control in development consists in taking off more pigment than would naturally come away. It is accomplished by pouring water over the print for broad areas, or by gently washing it with a tuft of cotton while it is under water, or by spraying water of different temperatures upon it from an atomizer. Small areas can be picked off with a brush while the print is under water, and larger areas on a tough, greatly overexposed print may even be subjected to water sprayed upon it from a rubber tube over the faucet. But in general, where the exposure is anywhere near normal, the print is very tender and all work upon it must be very gentle. A print that has been worked over with cotton or a brush is likely to show more granularity than one that has been regularly developed.

With long developments, the yellow stain of the bichromate is usually discharged, but if it still remains at the end of the development, it can be removed by 5 minutes in a bath of 5 per cent alum, after which the print is washed in two or three changes of water.

When development is complete, the print is laid on a sheet of glass which is tipped up for a few minutes to allow it to drain, after which it is left in a horizontal position until dry. Care has to be exercised in draining a very tender print so that the color will not run.

MULTIPLE PRINTING.—The full richness of the process is not obtained in a single printing. For multiple printing, the sensitizing coating is painted over the dry print and blended exactly as it was upon the plain paper, allowed to dry, and then the negative registered upon it as explained below, for subsequent printing. Multiple printing is used to build up the whole image, or to give added strength to local areas in the picture. The coating and the printing time are graduated to the needs of the areas to be worked upon. For example, great depth and richness can be imparted to the shadows by applying the coating only to the parts of the print in which they occur. Warmth can be added to flesh tones by giving one printing in a light red, among other printings of a darker color. The red printing will not show as such but will warm up the flesh tones. The paper should be re-sized before each printing if the previous development has been at all drastic, and it will probably be needed after two or three developments however gentle.

Registration for multiple printing is very easily obtained. Mask the negative with a frame of cardboard or paper about 1 inch larger than the negative. The printing paper should be slightly larger than the opening in the mask so that it projects on to the mask about $\frac{3}{8}$ inch all around. Before the first printing, the paper is laid over the negative so that it extends over on to the mask. A pencil line is then ruled from the top of the mask, over the print and down across the lower margin of the mask. Another pencil line is ruled at right angles to this from side to side across the mask and the paper. For subsequent printings, the paper is placed so that these pencil marks line up horizontally and vertically. If the paper stretches and shrinks, the print will

still be registered in the center and the variation will be progressive towards the edges and divided between the two sides of the negative so that in most cases it will be negligible.

COMBINATION PRINTING. — A combination of gum and platinum once had considerable vogue. An adaptation sometimes used at the present time when platinum paper is no longer commercially available, is to print a coating of gum over a contact print upon bromide or chloride paper. It is usually necessary to soak the bromide or chloride in water before applying the sensitizing mixture so that it will lie flat and not crawl upon the surface of the print.

CHAPTER XVI

THE CARBON PROCESSES

The carbon process derives its name from the fact that the pigment originally used in it was carbon, although one of the chief characteristics of the process is that it makes use of a great variety of pigments, affording almost unlimited choice of color. It is a long-scale process, reproducing quite faithfully the gradations of almost any negative. Carbon is a development of the process communicated to the Society of Arts for Scotland by Mungo Ponton in 1839, by which he secured images of drawings and dried flowers by printing through them on to a sheet of paper sensitized by a solution of potassium bichromate. The first practical method of pigment printing was introduced by Sir Joseph Wilson Swan in 1864, improved by J. R. Johnson in 1868, and brought to its final form by J. R. Sawyer in 1874.

The bichromated and pigmented gelatin is made insoluble in warm water in proportion as it has been acted upon by light, which means in practice, according to the different densities of the different parts of the negative under which it is printed. The soluble pigment is then washed out, revealing the image. As the insolubility proceeds from the front of the coating, where it is in contact with the negative, the parts under the shadows and halftones are still soluble after printing and would be washed away, taking the image with them, if development proceeded from the front. For this reason the *tissue*, which consists of a sheet of thin paper coated with the sensitized, pigmented gelatin, is transferred, face down, upon another support. The paper is stripped off, and development proceeds from what was the back of the emulsion when it was being printed. This leaves the picture in reverse, and to bring it the right way about, it is again transferred to a *final support*. If the negative has been reversed in the making, or if it is immaterial which way it appears, it can be left upon the so-called *temporary support* and the final operation dispensed with. As this materially shortens and simplifies the process, it is generally resorted to. If the negative is made especially for carbon printing the film can be reversed in the holder before exposure. Alternatively, a reversed negative may be made from a regular negative by projection, by facing the emulsion away from the lens in one of the operations. This method has the added advantage that the negative can be made any desired size, regardless of the size of the taking camera. Negatives upon film may be printed through the thickness of the film, with the image reversed, with very little loss of definition, especially if artificial light is used and it is kept at

considerable distance, so that the rays tend to become parallel. Before printing, the negative should be provided with a safe edge which need be no more than $\frac{1}{4}$ inch wide. It is conveniently made by sticking a strip of Scotch tape, or opaque paper, along all four edges of the negative. If the tissue is printed clear to the edges, it is difficult to handle it without damage.

Tissue in about thirty varieties of color, and transfer papers in a wide variety of surfaces may be obtained from George Murphy Inc., 57 East Ninth St., New York, the American agents for the makers, The Autotype Company of London, and their use is certainly advised, both for convenience and excellence of results, but the materials can be prepared by the worker according to the following formulas.

MAKING THE TISSUE.—The gelatin mass is prepared with hard and soft gelatin in the ratio of 3 to 1, or the finest pale carpenter's glue may be used, with an admixture of rock candy; in very hot, dry climates, add a little glycerin. The latter addition is not advisable under ordinary circumstances. A typical formula is:

Gelatin	3½ oz.	200 g
Rock candy	384 gr.	50 g
Water	16 oz.	1000 cc
Coloring pigment	30–77 gr.	4–10 g

Soak the gelatin and candy in the water for about 30 minutes and melt on a water bath. The pigment should be the finest powdered colors, as used by artists. It should be worked up with a muller on a sheet of glass with a little of the gelatin solution, and added to the remainder of the solution, well stirred, and strained through linen.

THE COLORS.—The colors can be mixed in various proportions, so that any shade may be obtained, and these should be judged by their appearance when mixed with a little of the gelatin solution and dried.

Chocolate brown.—India ink 6, English red 4, alizarin 1, dissolved in a little soda solution, purpurine 1 part.

Engraving black.—Lampblack 19, carmine lake 10, indigo 10 parts.

Warm black.—Lampblack 6, carmine lake 6, burnt umber 4, indigo 2 parts.

Dark brown.—Indigo 2½, Indian red 6, carmine 1¼, Vandyke brown 4, lampblack 30 parts.

Red brown.—India ink 6, carmine 8, Vandyke brown 8 parts.

Sepia.—Lampblack 4, sepia 35 parts.

Pure black.—India ink 15, Vandyke brown 2, Venetian red 2 parts.

Violet black.—India ink 20, indigo 2, carmine 1 part.

Red chalk.—English red 10, Italian red 5, lampblack 0.03 parts.

Transparency tissue for enlarged negatives and positives.—India ink 2, Indian red 3, carmine lake 5 parts.

TO COAT BY HAND. — Strain the warm mixture into a flat dish standing in warm water, and clear the bubbles off the surface with a strip of paper or thin card. Hold the paper to be coated upright at the further end of the dish, its lower edge just touching the liquid, and gently lower it on to the surface. Float for 2 minutes, and raise with a steady motion; allow to drip and hang up to dry.

SINGLE TRANSFER PAPER. — Brush over plain paper:

Soft gelatin	460 gr.	60 g
Water	14 oz.	875 cc

Soak the gelatin for 30 minutes, dissolve in a water bath, and raise nearly to the boiling point; add with constant stirring:

Chrome alum	10 gr.	1.25 g
Water	2 oz.	125 cc

The mixture must be rapidly used and kept hot, or it will gelatinize.

FLEXIBLE TEMPORARY SUPPORT. — Gelatinized paper is coated with a resinous solution. As a rule, a baryta-coated paper is used, either mat or glossy, which may be prepared as follows:

Gelatin	1½ oz.	100 g
Barium sulphate	230 gr.	30 g
Glycerin	38 minims	5 cc
Water	14 oz.	940 cc

Soak the gelatin in water, dissolve by heat, and add the baryta rubbed into a cream with the glycerin. Add very carefully, almost drop by drop, with constant stirring:

Chrome alum	13 gr.	1.6 g
Water	2 oz.	60 cc

Paint the mixture thickly over the paper, or float it twice, hanging up by opposite ends each time.

WAXING SOLUTION. — The temporary support has to be waxed prior to use, and the following may be used:

Beeswax	154 gr.	20 g
Powdered resin	154 gr.	20 g
Turpentine	16 oz.	1000 cc

Melt the wax in a water bath, add the resin, and stir until dissolved; then add the turpentine gradually with constant stirring. This should be applied to the paper with a pad, polished off with a dry pad, and then hung up to dry. It takes from 12 to 24 hours to dry; if ether be substituted for the turpentine, it will dry in a few minutes. *Caution.* — The water in the bath should boil,

and then the heat be removed, as the vapors of both turpentine and ether are explosive.

ALUM BATH FOR DISCHARGING BICHROMATE STAIN. —

Alum	1 oz., 43 gr.	62.5 g
Water	16 oz.	1000 cc

COLLODION FOR DOUBLE TRANSFER FROM OPAL. — This gives an extremely fine mat surface, without any glaze, if mat surface glass is used; if polished opal is used, a high gloss is obtained:

Pyroxyline	65 gr.	8.5 g
Alcohol	8 oz.	500 cc
Ether	8 oz.	500 cc

OPAL GLASS, IVORY, OR WOOD AS FINAL SUPPORT. — Coat with the chrome-gelatin mixture given above under single transfer paper. For canvas, the surface paint should be removed by scrubbing with hot soda solution, about 10 per cent, until nothing but the priming is left. Paint freely with the chrome-gelatin mixture, dry thoroughly, rub down smooth with fine sandpaper, and repeat the operations about four times. The print should be finally soaked in the gelatin solution, and squeegeed into contact, patting it down with the palm of the hand if the surface is rounded.

SUBSTRATUM FOR TRANSPARENCIES. — Either of the following may be used:

Gelatin	307 gr.	40 g
Water	16 oz.	1000 cc
Potassium bichromate	31 gr.	4 g

Coat the glass thinly, dry, and expose to light for 30 minutes; then wash and dry. Or the glass may be coated with the following, which keeps well:

Gelatin	54 gr.	7 g
Glacial acetic acid	260 minims	34 cc
Water	4½ oz.	270 cc

Soak the gelatin in the acid and water for 30 minutes.

Dissolve by heat, and add slowly, with constant stirring:

Alcohol	11 oz.	680 cc
Phenol (carbolic acid)	77 minims	10 cc

Then add, with constant stirring:

Chrome alum	5.7 gr.	0.75 g
Water	107 minims	14 cc

SENSITIZING. — The tissue has a pronounced tendency to curl, which sometimes makes it difficult to handle. If this tendency, which grows with the age

of the tissue, should be too pronounced, it can be overcome by suspending the tissue for a few minutes before sensitizing over a vessel of boiling water.

The standard sensitizer is:

Potassium bichromate	160-480 gr.	21-63 g
Water	16 oz.	1000 cc
Ammonia	q.s.	q.s.

Enough ammonia should be used to make the solution smell distinctly, which may require up to about 200 minims for the above amount of solution, depending upon the strength of the ammonia. For soft negatives, use the smallest amount of bichromate; for normal negatives, the mean; and for contrasty negatives, the greatest amount. From the same negative, a weak bath will give stronger prints, and a more concentrated bath softer prints. The temperature of the bath should be within a few degrees of 60° F. This is quite important because bichromated gelatin swells more readily than plain gelatin. Sensitizing may be done in full light, but the tissue must be dried in the dark, as it becomes sensitive while drying, which takes from 3 to 8 hours, depending upon the humidity of the drying conditions.

Immerse the tissue in the sensitizing solution for 3 minutes, keeping it moving all the time and handling it to prevent it from curling and keeping any part of it out of the solution. Break any air bells that may form on it, with a soft brush or with the finger-tips. Drain it for a couple of minutes and then suspend by one corner to dry.

Drying can be accelerated by laying the sensitized tissue face up on a sheet of glass and wiping off the surplus solution with a soft rubber squeegee, which must be as long as the shortest dimension of the tissue so that the whole surface will be included at one stroke, otherwise the end of the squeegee is likely to make a dent on the tissue which will persist through all subsequent manipulations. This operation is risky because the emulsion is very soft and easily injured, and it is safer to allow the tissue to dry naturally. Results are likely to be unsatisfactory if the air is so moist that drying takes more than 8 hours.

Tissue is in best condition for printing as soon as it is dry, but it may be kept in a cool, dry atmosphere for 2 or 3 days with little deterioration, or for a much longer time in airtight tin containers with a lump of calcium chloride, or wrapped in old newspapers which have been thoroughly dried by heat.

A formula containing citric acid will keep the tissue in good condition longer than the regular sensitizer, and is used by many occasional workers.

CITRIC ACID SENSITIZING SOLUTION

Potassium bichromate	240 gr.	20 g
Citric acid	60 gr.	5 g
Ammonia	q.s.	q.s.
Water	25 oz.	1000 cc

Dissolve the bichromate and the acid first in the water and then add ammonia gradually until it has changed the color of the solution from orange to lemon yellow, and the solution smells distinctly of ammonia. Printing time and contrast increase with the amount of citric acid used.

QUICK DRYING SENSITIZER. — A spirit sensitizer has the advantage that the tissue will be dry within half an hour.

STOCK SOLUTION

Ammonium bichromate	1 oz.	60 g
Water	16 oz.	1000 cc

This stock solution can be kept, like all the sensitizers mentioned above, for an indefinite time if protected from the light by wrapping the bottle in black paper. For use, take equal parts of the stock solution and of alcohol. The working bath should be used immediately, as it will not keep after the addition of the alcohol. This is applied to the tissue with an atomizer or with a Blanchard brush. In 5 minutes it will be surface dry, when another coating should be applied, after which it is hung to dry. Drying of tissue, however sensitized, can be hastened by gentle heat and the use of a fan.

PRINTING. — Carbon may be printed by daylight, arc light, mercury vapor, or by a sun lamp. As there is no visible image, the print must be timed by an actinometer. As a rough guide the time for tissue sensitized in a 4 per cent bichromate bath is about one-third that of printing-out paper. The printing time increases with the strength of the sensitizing solution, and it varies with the density of the negative, and with the color of the pigment used. Accepting black as normal, blues, purples, and greens will require less printing time, and browns, reds, and yellows more.

The printing frame for making carbon prints should be supplied with strong springs to keep the negative in good contact with the paper against its decided tendency to curl, and in damp weather the frame should include a sheet of rubber back of the paper to keep out moisture.

After tissue has been sensitized and dried, it gains in sensitivity for a short time and then begins to lose it. Allowance must be made for this, in timing prints, as printing times are not comparable except at the same interval after sensitization. The effect of light also continues for a time in the tissue after printing is stopped, even if it is stored in the dark, and the printing time must be adjusted to the interval that will intervene between printing and development. These two factors at their maximum may have considerable influence upon the character of the print. They can hardly be estimated, as they vary with conditions and so have to be learned by observation. It is well for the worker to standardize his procedure in this respect by printing at a fixed interval after the tissue is dry, and developing either immediately or at a fixed interval after printing. These intervals do not have to be calculated so closely as in terms of hours, but a day's difference in the operations may have a noticeable effect.

DEVELOPMENT. — After printing, the tissue is soaked in cold water until it becomes limp. Assuming that the print is to be made by single transfer, a sheet of single-transfer paper is thoroughly soaked in cold water, which may take an hour for thick, rough papers, and this time does no harm to smooth papers which may be conditioned in less time. The gelatin side of the transfer paper should be marked by pencil before it is soaked, as it is sometimes difficult to identify it when it is wet. The gelatin side of the transfer paper and the pigmented side of the tissue are brought together under water and the two papers in contact are withdrawn and placed on a sheet of glass or other hard, smooth surface and squeegeed into perfect contact to exclude all air and water. Place between hard blotters under a light weight of a pound or so to keep them from curling, for about 20 minutes. The bichromate stain showing through on the back of the transfer paper is an indication that this process is complete.

Immerse the adhering papers in water between 100° and 105° F. Very soon the pigment can be seen oozing out between the two papers, which are then gently stripped apart, keeping them all the time under water. The pigment paper is then thrown away and development commenced upon the transfer paper, to which most of the pigment has adhered. Agitate and gently splash the paper under the warm water until all the soluble pigment has been washed away, leaving the image in insoluble pigment on the paper. When the image is clear, transfer the print to cold water, and then to a 5 per cent solution of potassium alum in which it should be left until the yellow stain disappears. A final rinse in several changes of cold water completes the process, and the print is hung to dry.

CARBON PRINTS ON PORCELAIN. — The pigment used in carbon tissue for this process must be the special ceramic colors which resist any amount of heat. The tissue is sensitized and printed as in the regular carbon process and then the printed tissue and the porcelain article are soaked in water at 65° to 70° F. for a minute or two, until the tissue is limp, when they are withdrawn, face to face, and squeegeed or patted by the palm of the hand into contact, excluding all water and air bells. They are then covered with a piece of sponge rubber and left for 10 or 15 minutes under light pressure of a pound or two. At the end of that time the porcelain with the adhering tissue is placed in water at 105° to 110° F. and left until the pigment begins to ooze around the edges of the tissue. The tissue is then stripped off under water and the print developed by gentle laving with the same water in which the porcelain is immersed. After development, the print is rinsed in several changes of cold water, and set to dry.

The porcelain must now receive two firings, the first to burn out the gelatin, and the second to put a glaze over the print. The first firing is in an oven at 1200° F. and lasts until the dark brown color of the burning gelatin has given way to the original color of the print. The porcelain is then cooled and covered with a coating of glaze which is allowed to dry, and then fired again

in an oven at 1600° F. until the surface of the glaze changes from mat to glossy, when it is taken out before bubbles begin to form.

The print may now be hand-colored with ceramic vitreous dry colors mixed with oil of Copaiba and a little French fat oil, applied with a brush. After coloring, the color is made permanent by firing again at a temperature of 1600° F. until it becomes glossy.

DOUBLE TRANSFER. — In the double transfer process the print is developed upon a temporary support which has a waxed surface, to which the pigment will not adhere so strongly that it cannot be pulled off by the final support. Development upon the temporary support is similar in all respects to that in the single transfer method, and the developed print is given the alum bath and hung up to dry. The final support, which must be larger than the print, but smaller than the temporary support, should be soaked in cold water, then placed for 2 minutes in water at 90° F., and then returned to the cold water. The dry print upon the temporary support is placed in cold water until limp, then the two are squeegeed into contact and hung up to dry. When they are dry, the temporary support is pulled off, leaving the print upon the final support.

ARTIGUE AND FRESSON. — A carbon paper that could be used without transfer was first put on the market by V. Artigue in 1894, embodying the process used by F. Artigue in private since 1878, in which a mixture of gelatin, glucose, and sugar was dusted over with powdered pigment. Similar processes were used by Beauregard in 1857 and Blair in 1863. This process was popularized under the name of Fresson in 1900, with the pigment embodied in the mixture of colloids which consists of gelatin and sugar in a very thin coating. The commercially prepared paper is sensitized by immersion in a 1 per cent solution of potassium bichromate, at a temperature of about 60° F., and printed under a negative which is preferably quite thin. The printing time is determined by an actinometer, as in regular carbon printing, it being roughly equal to that required for printing-out paper. Longer exposure to a weak light increases contrast. A stronger solution of bichromate for sensitizing decreases contrast. Printing time depends upon the color of the pigment, blues taking less time and reds more. Development should follow printing without delay of more than a day.

Development is accomplished by washing in water as with regular carbon, but with a certain amount of friction, for which there has been devised a treatment with sawdust which is one of the unique features of the process. The commercially obtainable, non-staining whitewood sawdust is very fine, being sifted through a No. 120 mesh, and it is used in concentrations of from 10 to 50 per cent, depending upon the amount of friction needed. Infusorial earth, which is less abrasive, may be used instead of the sawdust. The printed paper is first soaked for 4 minutes, until it is limp, in cold water, taking care to

break any air bells that may form on either surface of the paper, and it is then immersed for 1 minute in water at 86° F. The print is then supported, face up, on a sheet of glass or upon a ferrotype tin, and developed by pouring the sawdust soup over it from a cup or pitcher.

The print is very tender and should never be touched by the hands. Local work can be done by pouring the abrasive from a container with a small spout directly on to the part that it is desired to reduce preferentially, and with the print under water the pigment can be gently stroked with a brush.

Underexposure is hopeless, as too much pigment leaves the print even under the gentlest ministrations. Overexposure can be helped by returning the print for a couple of minutes to the water bath at 86°, or in extreme cases by the use of Javelle water or one of the hyperchlorite solutions sold for laundry purposes.

Development is stopped by placing the print in cold water, after which it is suspended by one corner to drip and dry. After it is dry, the emulsion will be hard enough so that it can be slipped under water for a few seconds, the surplus moisture blotted off, and the print then dried again between hard blotters under pressure to make it flat.

The sawdust can be kept indefinitely by the addition of a few drops of carbolic acid or a bichloride of mercury tablet to prevent fermentation, or it can be kept in the dry state by spreading it out in a pan and allowing the water to evaporate. It should be cleaned of the accumulated pigment occasionally by washing it with hot water while suspended in a linen bag.

CARBRO.— This is a development of the *Ozotype* process patented by Thomas Manly in 1899, in which a sized and bichromated paper was printed under a negative until a visible image appeared. After this had been washed to remove the bichromate stain, a "pigment plaster" was squeegeed into contact with it. The plaster consisted of pigmented gelatin which had been sensitized by immersion for about 1 minute in:

Glacial acetic acid	50 minims	4 cc
Hydroquinone	12 gr.	1 g
Copper sulphate	12 gr.	1 g
Water	25 oz.	1000 cc

After from 30 to 60 minutes in contact, the papers were separated and the print developed by washing away the soluble gelatin, in water at about 110° F.

Ozotype was followed by *Ozobrome* which Manly patented in 1905, using a bromide print instead of the printed image of the previous process, thus obviating the necessity for an enlarged negative. With improvements by Howard Farmer in 1919, this became the carbro process, which gives a carbon print equal in all ways to one made by direct printing except in the matter of critical sharpness. In direct carbon the bichromated, pigmented tissue is made insoluble by the action of light through a negative, while in carbro a

similar effect is obtained by the reaction between the tissue and a bromide print with which it is placed in contact.

The advantages of carbro are that it does not require a large negative, that daylight is not required, that all the work except the making of the bromide enlargement can be done in full light, and that the image is not reversed by the process.

Trays for the carbro process should preferably be of rubber, glass, or porcelain. Enameled iron trays can be used if the coating is intact and not porous, but for safety they should be painted with a chemical-resisting varnish.

Smooth, semi-mat bromide papers are best adapted to carbro. Glossy papers usually give trouble. Chloride and chlorobromide papers are likely to give a faulty first print, but good ones subsequently. They can be conditioned by bleaching them in:

Potassium bromide	50 gr.	3 g
Potassium ferricyanide	150 gr.	9 g
Water	10 oz.	300 cc

and then washing until the yellow stain disappears, redeveloping, and washing again, after which they are all right for carbro. Rough paper is likely to trap air in the irregularities of the paper and prevent good contact with the tissue. Prints should be fully developed. If part of the shadow detail is lost by full development, the carbro print will still show it. Printing under a mask that leaves a white margin all around the print, provides an area of soluble gelatin that will prevent frilling.

The single transfer papers of the carbon process are used for carbro. The commercial product is better than any that can be hand coated, but any bromide paper with a soft emulsion can be used for a transfer paper by fixing out the silver emulsion in plain hypo and then washing. The back of the transfer paper should be marked by pencil when it is dry, so that it can be easily distinguished when it is wet.

Sensitizing.—Sensitizing is usually performed in two operations for which baths are prepared by diluting the following stock solutions.

CARBRO STOCK SOLUTION No. 1

Potassium bichromate	1 oz.	30 g
Potassium ferricyanide	1 oz.	30 g
Potassium bromide	1 oz.	30 g
Water	20 oz.	600 cc

For *working solution*, dilute 1 to 3. The stock solution is so nearly saturated that it sometimes crystallizes out in cold weather, in which case it should be heated until it is all in solution again before use. The working solution may be rebottled after use and kept for future use, as it keeps for a long time if protected from light.

CARBO STOCK SOLUTION No. 2

Glacial acetic acid	1 oz.	30 cc
Hydrochloric acid, C.P.	1 oz.	30 cc
Formaldehyde, 40 per cent solution	22 oz.	660 cc
Water	1½ oz.	45 cc

For *working solution*, dilute 1 to 32. The stock solution gradually precipitates a white sludge which may be ignored if the solution is decanted from the top without disturbing it. The second bath is short-lived under working conditions and must be prepared fresh at the time of use, and not more than a dozen 8 by 10 inch prints should be processed in 32 ounces of the working bath.

Both the stock solutions will keep well if protected from the light.

Working Directions.—The bromide print and the transfer paper, which must be large enough to overlap the print all around, should be put to soak in cold water about an hour before commencing work, so that they will be in condition when needed. Thin papers, both prints and transfer papers, may not need as much time as this, but the longer time will do no harm.

The tissue, which is the same as that used for carbon printing, is sensitized by immersion for 3 minutes in the No. 1 working bath, then drained for a few seconds and placed for about 20 seconds in the No. 2 working bath. The temperature of both baths should be the same, and between 60° and 65° F. Care should be taken to keep the tissue completely immersed all the time, in spite of its tendency to curl, and to break any air bells that may form on either the front or the back of the tissue.

The time of immersion in the second bath varies with conditions and can be learned only by experience. It may run from 10 to 60 seconds. Other things being equal, shorter times give harder prints. Different papers require different times for similar results. Soft water shortens the time, which should never be less than 10 seconds. If less time than this seems to be indicated, the working bath should be further diluted with an equal amount of water.

While the tissue is in the first bath, the print is withdrawn from the water and placed upon a sheet of glass in a level position. A squeegee is passed lightly over the print to make it adhere to the glass so that it will not slip during subsequent operations, and its surface then covered with water again. With the print thus ready and waiting, the tissue is taken from the first working bath at the end of 3 minutes, placed in the second bath for the predetermined number of seconds, and then withdrawn and squeegeed into contact with the print. This must be done quickly and carefully, first putting one end of the tissue in contact with an end of the print and then lowering the rest of the tissue down on to the print in such a way as to force out any air and water from between them. The tissue is then made to adhere to the print by several strokes with a soft rubber squeegee. If the print and the tissue slip after coming in contact, a double image will ensue. Instead of the glass support, professional workers use a board with a hinged strip of wood across one

edge. The edge of the print and of the tissue are placed in contact under the strip which is then pressed down on to them, holding them immovable in relation to each other during the rest of the operation. Just sufficient force should be used in squeegeeing to make the tissue adhere to the print. If too much pressure is applied, the tissue and the bromide print cannot afterwards be separated without tearing one or the other of them. If the pressure is too light, it will result in a light print, or in lack of contact which will cause an imperfection in the print.

The print and the adhering tissue are placed between waxed papers to exclude the air, so that they will not dry unevenly, and left under light pressure, just enough to keep them in contact, for 15 minutes. At the expiration of this time, they are gently pulled apart. The bromide print is dropped into a tray of water, and left to be redeveloped later, for making more carbros. The tissue is laid, face down, on to the transfer paper which has previously been withdrawn from the water in which it had been soaking and laid face up on the sheet of glass. The two are then squeegeed into contact and left between blotters, this time without the waxed paper, for about 20 minutes. Movement between the two papers in this operation does no harm.

Development. — At the end of 15 minutes, the adhering papers are placed in a tray of water at about 95° F. There should be a considerable volume of water so that the temperature will not fall off much in a few minutes. After a few seconds, pigment will be seen oozing out from between the two papers, which are then pulled apart with a steady movement, taking care to keep them under water all the while. The tissue is then discarded, and the image is developed in the pigment on the transfer paper by gentle laving, during which some control can be exercised as during the development of a carbon print, by directing the water against parts that need to be lightened.

When development has been carried as far as desired, the print is transferred to a 5 per cent solution of potassium alum to harden it and to discharge the bichromate stain, and then washed in two or three changes of cold water and hung to dry.

The original bromide print is thoroughly washed, redeveloped, and without fixation washed again, when it is in condition to make further carbros. Or, the redeveloped print may be dried and used at any later time. Succeeding prints from the same bromide show increasing contrast, and this should be allowed for in the timing in the second sensitizing bath if identical prints are desired.

Combined Bath. — The process is sometimes shortened by combining the two sensitizing baths into one. To 16 parts of stock solution No. 1, add 60 parts of water, and when thoroughly mixed, add 1 part of stock solution No. 2. This bath decomposes rapidly. It should not be used more than once, and will not give satisfactory results for more than 4 hours after mixing. The average time of immersion in this bath is about 2½ minutes, but like the second

bath in the regular process, the time has to be learned by practice, as it varies under different conditions between $1\frac{1}{2}$ and 4 minutes. The concentration of the bath may be changed if satisfactory results cannot be obtained within these time limits. Shorter time or greater dilution gives more contrasty prints, while a longer time or less dilution results in softer prints. Results with the combined bath are not so certain as with the two baths, and its use is not advised for beginners.

No Transfer. — Instead of transferring the print to a separate support, it may be developed directly upon the bromide print. In this case the sensitized tissue is left in contact with the print for 30 minutes, and then instead of stripping the papers apart, they are placed in water at 95° F. until the pigment begins to ooze, when the tissue is stripped off, under water, and discarded, and the carbro print developed upon the bromide print.

After the final hardening of the carbro print in alum, the underlying silver image must be dealt with. This is now in an unstable state and it can be removed entirely by fixing in hypo, or by Farmer's reducer, or it may be redeveloped under the carbon image to reinforce and strengthen it if it is weak. Whether the silver image is to be removed or redeveloped must be planned from the beginning so that the carbro print can be made strong enough to do without assistance, or left light enough so that it will need the reinforcement of the redeveloped silver image. Very interesting two-tone effects can be secured by using different colors of tissue over the black silver print, or the two colors may be matched so that they blend into one tone. If the carbro image comes out somewhat lighter than desired, the silver image may be only partly redeveloped, stopping development when sufficient strength has been secured, but the stability of the image cannot be guaranteed under these conditions.

This method is quite popular, the labor of making a bromide print for each carbro being offset by the labor and hazard of the transfer. The cost of the bromide paper and of the transfer paper being about the same, there is practically no difference in cost, while the opportunity of using the underlying image makes it possible to save some prints that would otherwise be lost.

CHAPTER XVII

MISCELLANEOUS PRINTING PROCESSES

RESINOPIGMENTTYPE. — A smooth paper is coated with hardened gelatin, sensitized for 3 minutes in a 5 per cent solution of ammonium bichromate, and dried in the dark. It is exposed to daylight under a *positive* until a weak negative image appears in brown. The paper is rinsed in several changes of water to wash out the bichromate stain from the background, then placed in water at about 120° F. until a relief is raised, which will be in 2 or 3 minutes. The print is then surface dried front and back by means of hard blotters and filter paper or a cloth. A mixture of melted resin and wax and pigment is applied with a soft brush to build up the image, using more force where it is desired to strengthen the image, and the surplus pigment then dusted off. The image is fixed by imbedding it in the gelatin by passing it through steam, or by spraying with an alcoholic fixative varnish such as is used by artists for charcoal or crayon drawings.

Resinopigmenttype is an adaptation of the *Powder Process* and the *Dusting-on* processes originally demonstrated by Garnier and Salmon in 1859, which were based upon Poitevin's patent of 1855. These processes were the result of efforts at that time to find a process for making absolutely permanent prints. Carbon in the form of finely powdered graphite was the chosen medium, and in the earlier processes it was applied in the powdered form to suitably prepared paper, before the carbon process was evolved into its final form with the pigment incorporated in gelatin on a paper base.

THE POWDER PROCESS. — This process is based on the fact that colloids lose their tackiness on exposure to light in contact with a bichromate. It is rarely used for paper prints, and its chief application has been for the preparation of reversed and duplicate negatives for photomechanical work, or for making ceramic enamels. For the latter process the image was produced on collodionized glass to facilitate stripping, and the image transferred to the enamel plaques.

The following are typical formulas:

Dextrine	307 gr.	40 g
White sugar	384 gr.	50 g
Ammonium bichromate	154 gr.	20 g
Water	16 oz.	1000 cc
Glycerin	10-40 drops	20-80 drops
Gum arabic	154 gr.	20 g
White sugar	192 gr.	25 g
Ammonium bichromate	154 gr.	20 g
Water	16 oz.	1000 cc
Alcohol	$\frac{3}{4}$ oz.	50 cc
Dextrine	368 gr.	48 g
Grape sugar	368 gr.	48 g
Potassium bichromate	368 gr.	48 g
Water	16 oz.	1000 cc
Gelatin	44.5 gr.	5.8 g
Rock sugar candy	3 oz., 177 gr.	194 g
Potassium bichromate	445 gr.	58 g
Water	16 oz.	1000 cc

Soak the gelatin and the candy in the water for 30 minutes, dissolve by heat, and add the bichromate.

Vogel gives the following two-solution formula:

Solution A

Gum arabic	1 oz.	160 g
Sugar	$2\frac{1}{2}$ oz.	400 g
Honey	$\frac{1}{2}$ oz.	80 g
Water	$2\frac{1}{2}$ oz.	400 cc
Alcohol	180 minims	60 cc

Use warm water to dissolve the gum, sugar, and honey, and then add the alcohol; to this should be added a few drops of glycerin in dry weather.

Solution B

Ammonium bichromate 10 per cent solution

For use mix 1 part solution A, 2 parts solution B, and 3 parts water, heat to 122° F. (50° C.) and filter twice.

Plate glass should be flowed with one of the above solutions, the excess drained off, the plate dried in a level position at 145° F. (63° C.), and exposed while still warm. As the powder adheres only to the unexposed parts, a transparency must be used and not a negative, if a positive is required. In bright sunlight the exposure will be from 1 to 2 minutes, or until the image is faintly visible. The plate should then be again warmed, until hotter than the room in which the work is carried out, and placed on a sheet of white paper. A fine powder, such as graphite, sifted on to the surface from a fine muslin bag, is gently brushed over the whole surface with a very soft brush.

As the unexposed parts absorb moisture, the powder will adhere, and gently breathing on the film will cause it to adhere more quickly. As soon as the image is intense enough, the excess powder should be brushed off, the plate coated with 2 per cent plain collodion, and, when this is set, immersed in a 5 per cent solution of alum until free from yellow stain, then rinsed and dried. Instead of using the collodion, the plate may be treated with:

Sulphuric acid	1 oz.	75 cc
Water	4 oz.	300 cc
Methyl alcohol	8 oz.	600 cc

until all yellow color disappears, then gently washed with water, and dried. The image is very tender and very liable to damage. If it is not to be stripped from the glass, it is advisable to give the glass a preliminary coating of a 2 per cent solution of sodium silicate.

DUSTING-ON PROCESS. — A thin coating of sugar, albumen, and bichromate on glass is exposed to daylight under a positive transparency until a faint image appears. If this is kept for a few minutes in a very damp atmosphere, as in a closet with towels saturated with water, it will retain a powdered mineral which is dusted on to its surface, in direct proportion as it has been protected from the light, thus giving a faithful reproduction of tones. This process has had some vogue as a means of making either positives or negatives direct, and it is also used for the decoration of ceramics by the use of vitrifiable colors.

THE PEPPER DUSTING-ON PROCESS. —

Solution A

White pepper	8 oz.	400 g
Benzole	20 oz.	1000 cc

Allow to stand for 24 hours with frequent shaking; then filter.

Solution B

Gum dammar	480 gr.	50 g
Benzole	20 oz.	1000 cc

Solution C

Solution of rubber benzole; tire cement will do.

For use mix 10 parts solution A, 1 part solution B, 1 part solution C, filter, coat any surface, and dry in the dark. Expose under a transparency for a few minutes in the sun, dust over with any dry litho or other color, or bronze. Finally brush clean with a soft brush.

E. J. Wall proposes a process with a technique somewhat resembling that of bromoil. The print, immediately after washing, is immersed in a bleaching solution as follows:

Copper sulphate	38 gr.	5 g
Nitric acid	46 minims	6 cc
Potassium bromide	4 gr.	0.5 g
Hydrogen peroxide	1 oz., 288 minims	100 cc
Water to make	16 oz.	1000 cc

The temperature must be maintained at 70° F. (21° C.) and the bleaching time varies with different emulsions from 5 to 20 minutes.

Any inert powder pigment may be used. It should be brushed on or sifted from an improvised fine-mesh cloth sieve. Uniformity of size of the pigment particles has a bearing on the elegance of the results.

NEGROGRAPHIC PROCESS (Itterheim).—Smooth, well-sized paper should be rather thickly coated with:

Gum arabic	4 oz., 170 gr.	250 g
Water	16 oz.	1000 cc

The gum should be in clear small lumps and preferably suspended in a fine muslin bag in the water, which may be warm. When all has dissolved, add:

Potassium bichromate	384 gr.	50 g
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When this has dissolved, add:

Alcohol	77 minims	10 cc
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The paper should be hung up to dry. The exposure, under a line drawing, is from 5 to 10 minutes in diffused light, or until the image is distinctly visible. Immerse in water, not too cold, until the lines show a distinct relief. The print should then be surface dried with a soft pad of cloth, and hung up to dry. Then coat with:

Shellac	384 gr.	50 g
Lampblack	2 oz., 277 gr.	150 g
Alcohol	16 oz.	1000 cc

The shellac should be dissolved first, filtered, and then the lampblack worked in. A flat brush or soft pad should be used for applying this to the print, which, after complete coating of the surface, should be immersed in a 2 to 3 per cent solution of sulphuric or hydrochloric acid, until on gentle application of a soft brush or pad, the black pigment comes away from the ground leaving the lines of a good intense black.

ANTHRACOTYPE (Sobacchi).—Well-sized paper should be coated with a gelatin solution:

Gelatin	253 gr.	33 g
Water	16 oz.	1000 cc

Allow to soak for 15 minutes, melt at 104° to 122° F. (40° to 50° C.), and filter. Immerse the paper for 10 minutes in water, then place face up on a sheet of glass, and lightly squeegee into contact, or a soft linen pad may be used. The edges of the paper should be turned up to the height of about $\frac{3}{8}$ inch (1 cm.) so as to form a dish, and the gelatin solution poured in, allowing 2 ounces per square foot (620 cc per square meter). As soon as the gelatin

has set, hang up to dry. This paper will keep indefinitely. To sensitize, immerse for 2 minutes in a 4 per cent solution of potassium bichromate, and dry in the dark; this paper will keep for about a week. Expose under a drawing from 12 to 60 seconds in sunlight until the image is faintly visible. Immerse in running or frequently changed water, until all trace of yellow disappears. Then immerse in water at 82° to 86° F. (28° to 30° C.) for 1 minute, immediately place face up on a sheet of glass or flat board, and remove surface moisture with fluffless blotters or a soft linen pad. Finely powdered lampblack or other powder should be dusted over the surface through fine muslin; a small sieve can easily be made from a lidless box. Then a soft round badger brush should be used with circular strokes to distribute the powder, which should adhere only to the unexposed parts. When the image is fully visible, the print should be exposed to the sun or in a moderately warm oven, not over 140° F. (60° C.), until completely dry. At this temperature the gelatin softens, and the powder sinks slightly into it. When thoroughly dry, immerse in cold water until it lies quite flat, then place face up on a board, and rub the surface gently with a soft pad until the ground is white. Should the powder not adhere sufficiently to the lines, the powdering operation may be repeated as often as necessary, a warm water bath being used each time, and, if necessary, the temperature raised a few degrees to thoroughly soften the gelatin. The print then requires only drying.

THE ANILINE PROCESS (Willis). — The basis of this process is the reduction of a bichromate by the action of light and the formation of an aniline color on the exposed salt by the vapor of aniline or like compound.

Well-sized paper should be floated on (Reynolds):

Potassium bichromate, saturated solution	16 oz.	1000 cc
Sulphuric acid	345 minims	45 cc

Or (Dawson):

Ammonium bichromate	1 oz., 360 gr.	104 g
Glacial phosphoric acid	323-968 gr.	42-126 g
Water	16 oz.	1000 cc

Or (Vogel):

Potassium bichromate	38.5 gr.	5 g
Phosphoric acid, sp. gr. 1.124	8 oz.	500 cc
Water	8 oz.	500 cc

Or (Weissenberger):

Potassium bichromate	1 oz., 332 gr.	100 g
Sulphuric acid	2 oz., 60 minims	133 cc
Water	16 oz.	1000 cc

The sulphuric acid in this formula may be replaced by 1 ounce, 456 minims (122 cc) of phosphoric acid of a specific gravity of 1.117.

Weissenberger gives the two following formulas:

Potassium bichromate	1 oz., 75 gr.	66.6 g
Potassium bisulphate	5 oz., 216 gr.	300 g
Manganese sulphate	205 gr.	26.6 g
Water	16 oz.	1000 cc
Potassium bichromate	1 oz., 138 gr.	75 g
Sodium acid phosphate	3 oz., 224 gr.	200 g
Magnesium chloride	1 oz., 138 gr.	75 g
Water	16 oz.	1000 cc

The latter is said to be the better formula.

Paper, which must be free from wood pulp, should be floated on one of the above for from 1 to 2 minutes and rapidly dried. Exposure in diffused light will vary from 10 to 60 minutes, according to the thickness of the paper on which the drawing is made. In sunlight the exposure will be about one-third of the time. Development is best effected by laying the paper at the bottom of a box to the lid of which is pinned a sheet of stout blotting paper moistened or sprayed with:

Commercial aniline	8 oz.	500 cc
Benzole	8 oz.	500 cc

The image should appear in a few minutes and will be a dirty blackish-green. The color is somewhat dependent on the duration of the aniline fuming; the shorter this is, the bluer the final print; the longer the time, the more blue-black the color. The fuming time is dependent on the exposure. When the image is intense enough, immerse the paper in water, running or frequently changed, until the whites are pure. If the whites will not clear, immerse the print in a 1 per cent solution of sulphuric or 3 per cent hydrochloric acid; then wash, and the green will be formed, which can be converted into blue by treatment with a 1 per cent solution of ammonia.

VANADIUM PRINTING. — This is also sometimes called Aniline black or Endemann's process. Aniline black is formed by the action of a vanadium salt. The sensitizer is:

Salt	238 gr.	31 g
Potassium bichromate	238 gr.	31 g
Sodium vanadate	0.33 gr.	0.043 g
Sulphuric acid	1 oz., 20 minims	65 cc
Water	16 oz.	1000 cc

Well-sized paper, preferably sized with a 2 per cent solution of gelatin, is floated on the above or the solution may be applied with a brush and dried. Exposure should be about 7 minutes in diffused light, and the print should then be exposed to the vapor of a 2 per cent solution of aniline in warm water, which should be heated in a dish. The image will appear in a brown color and the paper should then be exposed in a very damp room or box at 75° to 86° F. (24° to 30° C.) for about 2 hours, or until quite black. Finally, it should be washed with dilute ammonia, 1 to 6, and dried.

FEERTYPE AND PRIMULINE PROCESSES. — These processes are more applicable to fabrics than to paper. They are based on the light-sensitiveness of complex organic compounds, which under the action of light, form colored dye images.

Feer suggested the following:

Solution A

Sodium toluoldisazosulphonate	192 gr.	25 g
Beta-naphthol	192 gr.	25 g
Caustic soda	61 gr.	8 g
Water	16 oz.	1000 cc

This gives scarlet-red images.

Solution B

Sodium ditolyltetrazosulphonate	192 gr.	25 g
Metaphenylenediamine	154 gr.	20 g
Water	16 oz.	1000 cc

This gives brown images.

Solution C

Sodium ditolyltetrazosulphate	192 gr.	25 g
Resorcine	169 gr.	22 g
Caustic soda	122 gr.	16 g
Water	16 oz.	1000 cc

This gives orange images.

Solution D

Sodium ditolyltetrazosulphonate	230 gr.	30 g
Resorcine	154 gr.	20 g
Caustic soda	115 gr.	15 g
Water	16 oz.	1000 cc

Solution E

Sodium ditolyltetrazosulphonate	230 gr.	30 g
Alpha-naphthol	192 gr.	25 g
Caustic soda	54 gr.	7 g
Water	16 oz.	1000 cc

Solution F

Sodium ditolyltetrazosulphonate	230 gr.	30 g
Paraphenylenediamine	154 gr.	20 g
Water	16 oz.	1000 cc

Solutions A, B, C can be used alone; solutions D and E mixed in equal volumes for violet tones; or solutions E and F in equal volumes for blue tones.

After exposure, which is about 5 minutes in sunlight, the prints should be washed in water acidulated with hydrochloric acid.

The *Primuline* process was patented by Green, Cross, and Bevan. The process is as follows:

Primuline	253 gr.	33 g
Hot water	16 oz.	1000 cc

Filter, and immerse the fabric in the warm solution for about 10 minutes, wash thoroughly, and immerse for 5 minutes in:

Sodium nitrite (not nitrate)	51 gr.	6.6 g
Hydrochloric acid	115 minims	15 cc
Water	16 oz.	1000 cc

Dry in the dark. Exposure must be made under a positive, if a positive print is required. Then the print is thoroughly washed, and treated with one of the following developers.

For red tones:

Beta-naphthol	77 gr.	10 g
Caustic soda	100 gr.	13 g
Water	16 oz.	1000 cc

For orange tones:

Resorcine	19 gr.	2.5 g
Caustic soda	84 gr.	11 g
Water	16 oz.	1000 cc

For purple:

Alpha-naphthylamine	154 gr.	20 g
Hydrochloric acid	23 minims	3 cc
Water	16 oz.	1000 cc

For blacks:

Eikonogen	100 gr.	13 g
Water	16 oz.	1000 cc

For brown:

Pyrogallol	92 gr.	12 g
Water	16 oz.	1000 cc

The prints must be well washed after development, and if on fabric, ironed before quite dry. Unfortunately, it is almost impossible to obtain pure whites by this process.

Andresen suggested the following process:

Benzidine	176 gr.	23 g
Water	16 oz.	1000 cc

Boil until dissolved, and add:

Water	284 minims	37.5 cc
Sulphuric acid	284 minims	37.5 cc

Allow the mixture to cool; then with the aid of ice reduce the tempera-

ture to 41° to 50° F. (5° to 10° C.), and a copious precipitate should be formed. Add slowly:

Sodium nitrite (not nitrate)	138 gr.	18 g
Water	$\frac{3}{4}$ oz.	50 cc

Stir until a clear solution is obtained, and pour into:

Alcohol	80 oz.	5000 cc
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The diazobenzidine will be precipitated. Filter and wash with alcohol two or three times, and dissolve in:

Water	16 oz.	1000 cc
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During solution the water must be kept cooled down to 41° F. (5° C.). This precipitate must not be allowed to dry, as it is very explosive. Keep the solution cool, and float paper on the surface, or immerse fabrics completely. Dry in the dark, and expose under a positive. The developer may be a 2 per cent solution of amido-naphthol-sulphonic acid-5 or the corresponding acid-9 compound with 2 per cent caustic soda.

Andresen also patented the following process:

Water	5 oz.	150 cc
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Heat in a porcelain dish to boiling, and add:

Beta-naphthylamine	220 gr.	14.3 g
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Add slowly:

Hydrochloric acid, sp. gr. 1.19	160 minims	10 cc
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Stir until dissolved, and add, with constant stirring:

Hydrochloric acid	1 oz., 160 minims	40 cc
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Cool the thick paste with ice to 41° F. (5° C.), preferably by adding the ice to the liquid, and add, with constant stirring:

Sodium nitrite (not nitrate)	154 gr. .	10 g
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Filter into an ice-cold dish. Paper should be floated on the cold solution, or fabric immersed, wrung out, and dried in the dark. Exposure under a negative will be from 8 to 12 minutes in diffused light, and the image shows in a brown color on the yellow ground. Development should be effected with a 10 per cent solution of fused sodium acetate, which gives brownish-red tones. If alpha-naphthylamine be used, brownish-gray tones are obtained. Better colors are obtained by adding a little of the sensitizing solution to the developers. The prints should be subsequently washed, and dried.

Schoen patented the use of diazotized ortho-amido-salicylic acid and its compounds for obtaining colored prints on paper and fabrics, red tones being given, which can be altered by treatment with various compounds, such as ferric chloride, lead acetate, cobalt nitrate, lime or baryta water.

DIAZOTYPE. — The two previous processes are based upon the light sensitivity of certain complex organic substances known as *diazo* or *diazonium* compounds which possess the ability to couple with aniline to form a colored compound without a preliminary mordanting. Diazo compounds commercially coated upon paper are now furnished as a substitute for blueprint papers. Their chief advantage is that they can be developed by fuming with ammonia, or with some papers by sponging the coupling agent upon their surface, thus obviating the necessity of wetting the paper with its consequent stretching and shrinking which makes it impossible to preserve the exact dimensions of the original drawing. Diazo papers ordinarily yield a positive from a positive, but by using special types of diazo compounds which can act as their own coupling agents, papers have been made which give a positive from a negative, and are thus suited to general photography when a colored image is desired.

CHAPTER XVIII

PHOTOMECHANICAL PROCESSES

CLEANING ZINC AND COPPER.— For line work, very fine pumice powder should be applied with a felt pad or soft scrubbing brush and water and applied in the same direction as the original lines of the polish. For halftone work on zinc or copper, well-washed whiting made into a paste with water and a little ammonia should be used with a swab of absorbent cotton. Or, for copper, American polishing charcoal, with rounded end, may be used in straight lines with plenty of water.

PASSING OR GRAINING BATH FOR ZINC

Powdered alum	240 gr.	31.25 g
Nitric acid	24 minims	3.125 cc
Water	16 oz.	1000 cc

GRAINING BATH FOR COPPER

Chromic acid	176 gr.	23 g
Water	16 oz.	1000 cc

ALBUMEN SENSITIZER FOR LINE WORK ON ZINC

Albumen (white of egg)	176 minims	23 cc
(Or dried albumen)	(50 gr.)	(6.5 g)
Potassium bichromate	40 gr.	5.2 g
Water	16 oz.	1000 cc

Sometimes glue is added:

Albumen	2 oz.	60 cc
Fish glue	$\frac{1}{2}$ oz.	15 cc
Ammonium bichromate	$\frac{1}{2}$ oz.	15 g
Water	32 oz.	1000 cc

A few drops of ammonia are sometimes added.

Rolling up takes very thin photo-transfer ink. Develop by swabbing with wet cotton under water in a tray, or under a faucet. Where plates can be baked in an oven, halftone enamel may be used for sharper results.

FISH GLUE SENSITIZER

Fish glue	365 minims	47.5 cc
Ammonium bichromate	104 gr.	0.132 g
Water	16 oz.	1000 cc

Add enough ammonia to produce a bright yellow color. This film must be burned in after development.

INKING UP LINE PRINTS ON ZINC. — Use photo-transfer ink, thinned down with a very little turpentine, and apply with compo or fine nap leather roller.

DEVELOPING LINE PRINTS. — Immerse the plate in water to which a few drops of ammonia have been added, and rub with a swab of absorbent cotton.

HARD ENAMEL FOR ZINC

Fish glue	11½ oz.	650 cc
Fresh white of egg	2 oz., 120 gr.	130 cc
(Or dried albumen)	(71 gr.)	(9.2 g)
Ammonium bichromate	115 gr.	15 g
Ammonia	10 drops	15 drops
Water	16 oz.	1000 cc

Beat the albumen to a froth and mix in the glue and again beat up, allow to stand for 8 hours, then dissolve the bichromate, add the ammonia and filter through absorbent cotton. The following gives a much tougher film:

Fish glue	3 oz., 128 gr.	187.5 cc
Belting cement (Le Page's)	1 oz., 283 gr.	93.75 cc
Ammonium bichromate	120 gr.	15.6 g
Albumen	3 oz., 128 gr.	187.5 cc
Ammonia	60 minims	7.8 cc
Water	16 oz.	1000 cc

Or:

Solution A

Belting cement (Le Page's) ..	5 oz., 212.5 gr.	312.5 cc
Chromic acid	21.75 gr.	2.85 g
Ammonia	85 minims	11 cc
Water	16 oz.	1000 cc

Solution B

Pure rock candy	1 oz., 85 gr.	68 g
Ammonium bichromate	262 gr.	34 g

Add the acid to the water, then the ammonia and finally solution B with constant stirring.

HARDENING BATH FOR ENAMEL PRINTS ON ZINC

Ammonium bichromate	27.5 gr.	3.55 g
Chromic acid	2.3 gr.	0.3 g
Methyl alcohol	2 oz., 223 minims	143 cc
Water	16 oz.	1000 cc

Immerse the developed plate for from 3 to 5 minutes.

DYE SOLUTION FOR FISH GLUE PRINTS. — 0.5 per cent solution of methyl violet or eosine.

HALFTONE ENAMEL FOR COPPER

Fish glue	12 oz.	360 cc
Ammonium bichromate	1½ oz.	55 g
Water to make	32 oz.	1000 cc

The glue is stirred into the bichromate solution. The film must not be thin enough to show any interference colors.

Cold water development takes 3 or 4 minutes. A longer time indicates overexposure. Dyeing the plate is unnecessary unless the exposure is uncertain. An open gas stove or electric oven may be used for burning-in.

An enamel more sensitive to light, is made by the addition of albumen.

Fish glue	3 oz., 224 gr.	200 cc
Albumen	2 oz., 44 minims	131.25 g
Ammonium bichromate	213 gr.	27.77 g
Ammonia	25 drops	33 drops
Water	16 oz.	1000 cc

Beat the albumen to a froth. Allow it to stand for 8 hours and add the glue and then the salts dissolved in some water. Make up to bulk and filter.

DEFECTS. — Eastman Kodak Company lists the causes of scum: dots insufficiently opaque from underexposure of the negative, dots printed through when the printing frame is too close to the light, coating fogged at some stage of the process, glass too hot in printing or overheating of the plate in drying, use of a naked gas flame in drying, want of proper contact, overexposure, lack of washing after exposure or dyeing, old or spoiled solutions.

If the enamel comes off it may be due to plates that are not clean or to the use of unsuitable enamel or enamel that is too thin or overbaked, or the perchloride of iron etcher may be too acid. To remedy this, add ammonia until the precipitate no longer dissolves.

BITUMEN PROCESS

Syrian asphalt (fine powder)	320 gr.	42.5 g
Chloroform	6 oz., 192 minims	400 cc
Benzole	9 oz., 228 minims	600 cc
Venice turpentine	96 gr.	12.5 g
Oil of lavender	32 drops	40 drops

The coated film should be a transparent golden color. The exposure is very long even in sunlight. Develop with rectified turpentine.

ETCHING BATHS FOR ZINC. — Weak bath for first bite for line or halftone, 1 per cent nitric acid. Deep etching for halftones, $2\frac{1}{2}$ per cent nitric acid. For fine etching halftones on zinc, 1.875 per cent.

For cold enamel:

Nitric acid	120 minims	15.6 cc
Alcohol, 40 per cent	16 oz.	1000 cc

The exposed image is not burnt in, only heated to dry and harden.

SCUM REMOVER FOR COPPER

Acetic acid	698 minims	100 cc
Common salt	3 oz.	187.5 g
Water	16 oz.	1000 cc

The same quantity of hydrochloric acid may be used instead of the acetic.

COLLOTYPE. — *Grinding New Plates.* — Sift over the surface finely sifted emery powder, wet well with water and grind with another plate with circular motion. Wash well after grinding.

Cleaning Old Plates. — Soak in 5 per cent caustic potash solution for 4 days or place in hot 10 per cent solution of sodium carbonate. Scrape off old film with hard brush. Regrind before use.

Substratum

Whites of fresh eggs	5 oz.	312 cc
Sodium silicate	2 oz., 85 gr.	125 g
Water	16 oz.	1000 cc

Beat the whites to froth and allow to settle, filter and add the other ingredients. Pour a little on the plate, drain slightly and place on leveled stand to dry. Or:

Solution A

Gelatin	115 gr.	15 g
Water	8 oz.	500 cc

Solution B

Alum	80 gr.	10 g
Water	8 oz.	500 cc

Dissolve the gelatin by heat, add the alum solution warmed up, and add:

Sodium silicate solution	350 gr.	46 g
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The plates should be warmed and the solution applied with a broad camel's-hair brush and dried. A stock of plates may be thus prepared, but they should be rinsed in water and again dried.

Sensitive Solution

Hard gelatin	350 gr.	46 g
Water	16 oz.	1000 cc

Allow to soak for 30 minutes and melt and add:

Potassium bichromate	126 gr.	16.5 g
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and filter. Allow 44 minims to every 100 square inches (682 cc per square meter). Place the plates in the drying box and warm up to 120° F. (48° C.), carefully level and coat. The temperature of drying must not exceed 130° F. (54° C.). After exposure wash in water at 60° F. (15° C.) until all trace of yellowness has disappeared, then dry.

Etching the plate is actually a moistening process, there being no etching action. The plate should be rinsed in water, blotted off and covered with a mixture of 3 parts glycerin and 2 parts water for about $\frac{1}{2}$ hour. Or equal parts of glycerin and water plus 2 per cent of ordinary salt may be used.

MACHINE ETCHING. — Levy machine, first etch, 10 per cent acid for 30 to 40 seconds; second etch, 15 per cent for 1 to $1\frac{1}{2}$ minutes; third etch, 20 per cent for 4 to 5 minutes. Air pressure for first etch, $\frac{1}{4}$ to $\frac{3}{4}$ pound; second and third etches, 1 pound. A single etch with 10 per cent acid for 30 to 40 seconds is generally enough except for extra deep work. For Holt machine and line work on zinc, 7.5 per cent with three bites and rolling up between. Total time for full depth, about 18 minutes. For halftone on zinc, use the same solution as for line work, for $1\frac{1}{2}$ minutes; then roll up and powder, and etch for 2 minutes.

For halftone on copper use perchloride of iron solution 35° B. or a 35 per cent solution of anhydrous ferric chloride. Air pressure $\frac{1}{2}$ to $\frac{3}{4}$ pound, time for first bite 30 seconds and total time $3\frac{1}{2}$ to 4 minutes after stopping out. If the iron solution is very acid, add a little ammonia until a slight precipitate is formed, then boil and filter.

PHOTOGRAVURE. — Negatives should be full of detail and without hardness and preferably carbon transparencies should be made, showing all details in the highlights, without great density. The thinner these are kept, providing details in the highlights are visible, the better. Special transparency tissue is issued by the makers, or standard brown may be used.

Cleaning the Copper Plate. — Rub over with a 5 per cent solution of potassium carbonate with a cotton swab, rinse well, and treat in the same way with a 5 per cent solution of sulphuric acid. Wash well and polish with whitening made into a paste with a 3 per cent solution of ammonia. Rinse the plate with hot water and dry with a clean cloth.

Graining the Plate. — The usual dusting boxes should be used and the longer the time between setting the powdered asphalt in motion and the insertion of the plate, the finer the grain. For a coarse grain wait for 20 seconds. Allow the plate to remain for from 2 to 5 minutes. For very fine grain it may be necessary to shake the box and grain two or three times. Resin may be used but does not give such good results in unskilled hands.

Setting the Grain. — Grip the edge of the plate with a hand vise, using a card to protect the copper, and heat over a gas flame, with continual movement so as to even the heat, until a steel-blue color shows.

Mounting Resist. — Place the grained plate in water at 70° F. (21° C.), slip in the tissue, and brush the face with a soft brush to remove air bubbles. Bring the two into contact and lift from the water, squeegee well, and place between blotters for 10 minutes. Develop with water at 100° F. (38° C.) or if underexposed, raise the temperature to 120° F. (49° C.). Rinse in cold water and dry. If etching is to be done at once, flow over with equal parts of methyl alcohol and water and dry on whirler.

Varnishing. — The back and edges of the plate should be painted with a 20 per cent solution of bitumen in benzole or Mogul varnish thinned down.

Etching Solutions.—Anhydrous ferric chloride is used. It is advisable to add to this 6 per cent of freshly precipitated ferric hydroxide, and cover with distilled water, and make solutions up to 43°, 40°, 38°, 36°, and 33° B. with distilled water. The following strength solutions correspond to the above: 43° = 46 per cent; 40° = 41 per cent; 38° = 39 per cent; 36° = 36 per cent; 33° = 33 per cent. To each of these the ferric hydroxide may be added, well shaken, and allowed to settle for use, or the whole solution made up very strong, heated with the hydroxide, and then diluted to the above strengths. The weaker the solution the stronger the etching. As soon as etching is complete, rinse the plate, immerse in 10 per cent solution of caustic potash, and rub with a swab of cotton. Then rinse, dry, remove grain with benzole, clean plate with 1 per cent nitric acid, and finally with washed whiting and ammonia.

PHOTOLITHOGRAPHY. — Transfer paper should be sensitized with a 4.5 per cent solution of potassium bichromate, rendered alkaline with ammonia in winter and with the following in summer:

Potassium bichromate	173 gr.	22.5 g
Manganese sulphate	24 gr.	3.15 g
Water	16 oz.	1000 cc

Temperature of bath 60° F. (15° C.); time of immersion 5 minutes. It is as well to squeegee the paper to plate glass so that it may dry with a polished surface. After printing, place on rolling-up board and apply the ink in a very thin film with a velvet roller. Place in water for about 3 minutes and then roll up again with the roller; this removes the ink and any slight veil can be removed with a wet swab of cotton. Free from water drops by lightly touching with blotting paper and pin to a board to dry.

The multiplication of designs, as in the case of label printing, is done by making one small original plate, the proofs of which are pasted on a waterproof card or metal plate covered with paper, to be put down on a large plate, or by elaborate "step and repeat" devices, and arranged in a composite. This replaces negative making on wet collodion and stripping the film for composite negatives.

DIRECT PRINTING ON ZINC AND ALUMINUM. — Sensitize with:

White of egg	1 oz., 43 minims	62.5 cc
Fish glue	$\frac{1}{4}$ oz.	15.6 cc
Ammonium bichromate	60 gr.	7.8 g
Ammonia	q.s.	q.s.
Water	16 oz.	1000 cc

Enough ammonia should be added to make the solution a clear lemon yellow. For large plates the volume of the solution may be increased by one-quarter with water.

Sensitizing formula recommended by Eastman Kodak Company:

Albumen	4 oz.	114 g
Ammonium bichromate	100 gr.	13 g
Water	32 oz.	1000 cc
Ammonia	20 drops	15 drops

The bichromate is dissolved in one-half the quantity of water and the albumen in the other half. Mix when dissolved and add the ammonia. Another formula is:

Albumen	3½ oz.	100 g
Water	30 oz.	900 cc
Ammonium bichromate	½ oz.	14.2 g
Water	2 oz.	100 cc
Ammonia, 25 per cent	1 oz.	50 cc

The addition of other ingredients such as fish glue may cause the image to lift during the printing. Filter the completed solution through cotton to remove solid impurities and air bells.

The metal plates must be chemically clean and free from grease. They are then "counter-etched." A plate washed with acetic acid and rinsed, and another soaked in bichromate and rinsed clean, are quite different. Copper sulphate will blacken the first one but not the second. The ink will take only on the acid-washed metal.

The plate is whirled and treated with a 1 to 16 solution of acetic acid and swabbed over with cotton. After washing it is coated with the sensitized albumen and whirled at 60 rpm until dry. It is then printed by arc light for 1 to 5 minutes, and developed by rolling up with photo-transfer ink thinned down with turpentine, or swabbed over with an ink of the consistency of cream:

Transfer ink	½ lb.	454 g
Best quality printer's ink	½ lb.	454 g
Engraver's etching ink	½ lb.	454 g

Grind them up in 16 ounces (473 cc) of turpentine and then add 20 drops of oil of lavender. Thin down with rectified turpentine. When rolled up or swabbed over evenly, the solvent is then allowed to evaporate, the plate is flowed with cold running water and rubbed over lightly with cotton. The albumen that still remains soluble is loosened, together with its ink coating.

Sometimes rolling-up ink is used on the wetted plates to roll up the scum and to protect the finer lines in the etching. Many prefer to dry first, then gum up and dry again, wash and roll up, or to use the arc light again to ensure the insolubilization of the bichromated albumen.

After development, the wet plate is stood up on edge to drain off the excess water and the following solution is then brushed rapidly over the entire surface with a soft brush and allowed to remain on the plate for 2 or 3 minutes:

Strong gum arabic, 30 per cent solution .	16 oz.	1000	cc
Water	16 oz.	1000	cc
Ammonium bichromate	1 oz.	57	g
Syrupy phosphoric acid	$\frac{1}{2}$ oz.	28.5	cc

Scummy plates give inferior results. Wash off the etcher, wipe off the excess water, and gum up and dry. Patented improvements on this method have been put out by the Lithographic Technical Foundation and are available under license.

VANDYKE OR REVERSE PROCESS. — Zinc plates should be grained with the graining bath given for line work and coated with the following:

Fish glue	853 minims	111	cc
Ammonium bichromate	170 gr.	22	g
Chromic acid	1 gr.	0.13	g
Water	16 oz.	1000	cc

After exposure, under a line copy, develop with plain water and dye up with aniline dye. The plate should then be passed into a bath of:

Ferric chloride, 31 per cent solution ..	16 minims	2	cc
Water	16 oz.	1000	cc

Leave the plate until the color disappears, then rinse and dry. Treat the plate with asphaltum washout tincture, and ink up with the following:

Bitumen (powdered)	4 parts
Litho chalk printing ink	1 part
Litho writing ink	1 part
Burgundy pitch	1 part

Mix with heat and thin with the minimum of turpentine. There must be but a very thin film of ink on the plate. Allow the plate to dry, and develop with water, plain or very slightly acidulated with hydrochloric acid.

CALCULATING STOP SIZES. — Any stop other than $1/64$ of the camera extension (equal to $f:32$ in copying same size) is a satisfactory one to use if calculated correctly. If it were $1/90$ of the camera extension, with a 150-line screen, using an 18-inch lens for same-size copying, the camera extension works out at 36 inches. The stop is $36/90$ inch, or 0.4 inch. The screen opening is $1/300$ inch, and $36 \times 1/300 + 4/10$ gives 0.3 inch for the screen distance, which should be ninety times the screen opening, because the camera extension is just ninety times the size of the stop diameter.

Mechanical devices with scales attached are often used to give directly the facts as to screen distances, exposure, etc., which save the time and trouble of calculating and speed up the work.

PRISMS. — The right angle, total-reversing prisms, like the mirrors that replace them in the very large sizes, serve to invert the image one way only. The camera, lens, and stand must all be true, the important things being the

centering of the lens and prism and their optical relations to the copy-board and the groundglass. Optical reversal, inversion of the image one way only, occurs with prisms when reversed negatives or positives are needed, otherwise the negative or positive film has to be stripped from its support and turned over, or new negatives or positives made by copying or projection. In some cases, film negatives are thin enough to print backwards.

Prisms are ordinarily mounted in front of the lens, but sometimes they are placed behind the lens on the camera front in the same way that large mirrors are used.

In photomechanical work the copy-board is parallel to the lens axis but is still vertical and the front surface of the prism must be absolutely normal to the lens axis and truly parallel to the free face carrying the prism cap. Any deviation will cause distorted and misplaced images. When the copy-board is horizontal, the prism points downward and likewise must be true in its relation to the lens and groundglass screen.

Prisms can be used only for narrow angle work because internal reflections may develop which, in extreme cases, may show on each end of a copy a duplicate image of the other end, overlaying the actual image.

HALFTONE SCREEN OPTICS. — The size of the diaphragm or the screen separation, or both, can be varied. This distance is measured from the actual screen surface and glass covers must be allowed for. Refraction errors due to glass thickness may be subtracted or ignored, as they are small. In practice, the screen distance for every reduction is kept constant, and the stop is altered when the reduction is changed, to keep the ratio between the stop and the camera extension equal to the ratio between the distance of the screen from the plate and the screen opening.

HALFTONE SCREEN DISTANCES
(Stop $1/64$ of camera extension)

<i>Lines per inch</i>	<i>Actual space in inches</i>	<i>Distance screen ruling in inches</i>	<i>In 1/32 inches</i>	<i>In milli meters</i>
50	1/100	64	20.5	16.2
65	1/130	49	15.7	12.4
80	1/160	40	12.8	10.0
100	1/200	32	10.3	8.1
120	1/240	27	8.6	6.8
133	1/266	24	7.7	6.0
150	1/300	21	6.8	5.4
175	1/350	18	5.8	4.7
200	1/400	16	5.1	4.1

CHAPTER XIX

STEREOSCOPIC PHOTOGRAPHY

The stereoscope is an instrument for assisting the observer to bring into coincidence the images of two pictures taken from points of view that are some distance apart, usually the same distance that separates the pupils of the eyes, thus giving the appearance of solidity and of the third dimension normally secured by binocular vision. These pictures were originally line drawings, since the stereoscope was invented before the discovery of photography, but the principles of stereoscopy were early applied to photography, the first camera for this purpose having been invented by Sir David Brewster in 1847.

The distance between the pupils of the eyes varies with the individual from about $2\frac{1}{8}$ inches to 3 inches, the mean being about $2\frac{1}{2}$ inches (63 to 65 mm), which distance is generally used for the separation of the lenses in making stereoscopic pictures. Some cameras have a means of adjusting this separation, which is made less for near objects and greater for distant objects. The range of stereoscopic effect in photography is not more than 80 yards and the effect falls off rapidly at even much shorter distances. The inter-lens distance is increased to exaggerate this effect at longer distances, and it is also enhanced by including some near object in an otherwise distant scene.

Stereoscopic photographs can be made with single lens cameras by making two exposures and moving the lens an appropriate distance between the two exposures. For mapping and for celestial photography this distance is sometimes made far greater, even up to miles apart.

For convenience, in ordinary stereoscopic photography, a twin-lens camera is used. The lenses must be matched as to focal length and the diaphragms used at the same opening to secure the best results, although tolerable stereoscopic effects can be secured when there is some discrepancy in these respects.

The pictures may be made either as prints or as transparencies, depending upon the type of viewing apparatus for which they are intended. The transparencies give rather the better effect but prints are very largely used on account of the inexpensive apparatus with which they can be viewed.

On account of the reversal in the camera, the prints or transparencies have to be reversed, putting the picture from the left-hand negative on the right-hand side of the print or transparency so that it will be viewed by the eye corresponding to the lens of the pair that took the picture.

From time to time there have appeared various devices, making use of mirrors or reversing prisms, for viewing stereograms printed without transposition from a pair of pictures taken upon a single plate, but none of these devices ever came into popular use.

SIZES OF STEREOS. — The original stereographic pictures were taken upon plates, making images about 3 inches square, but in later years this size was somewhat reduced. The sizes in most common use are $2\frac{3}{4}$ by $5\frac{1}{8}$ inches (7 by 15 cm), $2\frac{3}{8}$ by $5\frac{1}{8}$ inches (6 by 13 cm), $1\frac{3}{4}$ by $4\frac{1}{4}$ inches (4.5 by 10.7 cm). In an effort to standardize the sizes, the International Congress of Photography in Brussels in 1910 authorized "all sizes which can be held in a frame formed by two squares of side 80 mm ($3\frac{1}{8}$ inches) placed side by side, it being assumed that homologous points of an object at infinity must not under any circumstances be more than 80 mm ($3\frac{1}{8}$ inches) apart and that a smaller distance is preferable." The size of the picture shown varies from $1\frac{1}{2}$ by $1\frac{5}{8}$ inches to $2\frac{1}{2}$ by $2\frac{3}{8}$ inches. In all cases the pictures are separated by at least $\frac{1}{8}$ inch and in the smaller sizes, at greater distances up to $1\frac{1}{2}$ inches so that homologous points in the pictures will be separated by about $2\frac{1}{2}$ inches.

STEREOSCOPIC PROJECTION. — While stereographs are usually viewed in apparatus which shows them in their original size, there are various methods of projecting them on a screen so that they may be seen stereographically. One of the earliest means used for this purpose was by the use of *anaglyphs*, which consisted of two images made in different colors and viewed by the observer through spectacles of the complementary colors.

The same effect is secured by polarizing in different directions the light projected through the two pictures, each observer being equipped with binoculars similarly polarized. Care must be taken that projection is made upon a screen, like groundglass or metallic paint, which does not depolarize the light.

Stereoscopic projection is also obtained by special optical devices of mirrors and prisms, or by a mask permitting each eye to see only one image.

CHAPTER XX

LANTERN SLIDES

Lantern slides are transparencies upon glass or film for projection with a stereopticon upon a screen. The standard size in the United States and Canada is $3\frac{1}{4}$ by 4 inches. The standard size in England and the British dominions except Canada is $3\frac{1}{4}$ by $3\frac{1}{4}$ inches. In Europe the size is 85 by 100 mm (about $3\frac{1}{2}$ by 4 inches). Standard projectors take these slides only in the horizontal position, but special apparatus is often used that will show the slides either horizontally or vertically, and in larger sizes up to 5 by 7 inches. For slides from miniature negatives, especially in direct color, small projectors taking a slide 2 by 2 inches are much used for amateur work.

The emulsions upon lantern slides are either chloride, bromide, or chlorobromide. The chloride emulsions are used for contact printing, while the bromide or chlorobromide may be printed either by contact or projection. Contrast may be varied by development, but the larger manufacturers furnish lantern plates in two or three different degrees of contrast.

PRINTING. — If the image on the original negative is of suitable size, the slide may be printed by contact, but this is so seldom the case that most slides are printed by projection. Printing by projection also affords the same opportunities for control that are exercised in making enlargements on paper. Holding back local areas while printing, printing them deeper, and adding clouds to a landscape from another negative are forms of control regularly used in making slides by projection.

The density of the slide is determined by the amount of exposure. Desirable density depends upon several factors such as the strength of the light in the stereopticon, the distance between the stereopticon and the screen, and the reflecting power of the screen. Slides made for a long throw, as in a public hall, must be made thinner than those which will be shown in the home or in small assembly rooms, if the strength of the projection light and the reflecting power of the screen are the same. As these factors vary so greatly, it will be seen that the average density of slides must be determined by the worker to suit his individual requirements. If the screen and the light factors are made constant, variations up to 100 per cent in the projection distance can be made without serious loss of quality in the projected image. Greater differences in distance can be compensated for by different combinations of strength of projecting light and reflecting surface of the screen.

As all mechanical blemishes in lantern slides show up very noticeably and unpleasantly under the great degree of magnification to which they are subjected, the original negative should be scrupulously clean and free from dust while it is being printed. Some spotting may be done upon the negative or upon the slide, but only the finest work will stand the great enlargement acceptably, and it should be kept to a minimum.

DEVELOPMENT. — Lantern slides may be developed with almost any kind of developer, but best results are secured with developers especially compounded for them. While the wisest course is to follow the manufacturer's recommendation in this respect, Nepera solution is an ideal developer for many kinds of lantern slides and is quite generally used, while amidol is a favorite with many workers when blue-black tones are desired.

AMIDOL LANTERN SLIDE DEVELOPER

Amidol	32 gr.	4 g
Sodium sulphite	192 gr.	25 g
Potassium bromide	16 gr.	2 g
Water to make	16 oz.	1000 cc

The sulphite should be dissolved first in about 12 ounces of water, then add the amidol and the bromide and bring the total bulk up to 16 ounces.

Hydroquinone is also a very suitable developer and the following formula in two solutions keeps well if stored in bottles filled to the top, and may be kept in stock, ready to mix and use.

HYDROQUINONE LANTERN SLIDE DEVELOPER

Solution A

Hydroquinone	64 gr.	8.5 g
Potassium bromide	96 gr.	13 g
Potassium metabisulphite	64 gr.	8.5 g
Water to make	16 oz.	1000 cc

Solution B

Caustic potash or	128 gr.	17 g
(Caustic soda)	(90 gr.)	(11.5 g)
Water to make	16 oz.	1000 cc

For use, take equal parts of solutions A and B. Use at a temperature not below 65° F. (18° C.).

Warm Tones. — Considerable variation in the color of the image can be made by the use of different developers and by combinations of different lengths of exposure and compensating amounts of potassium bromide in the developer. The chlorobromide emulsions lend themselves particularly well to this treatment, although any emulsion can be manipulated to a certain extent. It is possible to obtain colors ranging from blue-black through brown and olive to red and orange. These colors add variety to the slides and may be used appropriately for different subjects. Colors so obtained are likely to be more permanent than similar colors obtained by toning.

Very pleasing warm blacks and browns are easily secured by using a pyro-ammonia developer which keeps well in the two-solution formula.

PYRO-AMMONIA DEVELOPER

Solution A

Pyro	48 gr.	6.25 g
Sodium sulphite	192 gr.	25 g
Citric acid	5 gr.	0.625 g
Water to make	16 oz.	1000 cc

In making up this solution, dissolve the sulphite and citric acid in about 12 ounces of water, and then add the pyro and bring the total bulk up to 16 ounces.

Solution B

Ammonium bromide	64 gr.	10.5 g
Liquor ammonia, sp. gr. 0.880	48 minims	6.25 cc
Water to make	16 oz.	1000 cc

Take equal parts of solutions A and B. If the color is not brown enough, add further ammonium bromide from a 10 per cent stock solution, increasing exposure as may be necessary. In a general way, the above pyro formula will require five times the exposure given the plate for a black tone with either of the developers already given.

The greatest range of tones is secured on chloride or chlorobromide emulsions and the following methods are particularly applicable to them, but they may be used effectively upon almost any kind of lantern plate.

METOL-HYDROQUINONE

Solution A

Metol	16 gr.	2 g
Sodium sulphite	80 gr.	11 g
Sodium carbonate	320 gr.	42 g
Hydroquinone	16 gr.	2 g
Potassium bromide	16 gr.	2 g
Water to make	16 oz.	1000 cc

Dissolve these ingredients in the order given.

Solution B

Ammonium bromide	1 oz.	60 g
Ammonium carbonate	1 oz.	60 g
Water to make	15 oz.	1000 cc

This developer will yield slides ranging from black to red, according to the exposure, and the dilution and restraining of the developer. Slight variations in the plate will sometimes affect the result, but the following is right for the majority of brands. When warm tones are required, exposures must be considerably increased and additions of solution B made, solution B not being required when cold blacks are wanted. The following table has been published

by Wellington and Ward of Elstree, England, and should prove a valuable guide.

<i>Color</i>	<i>Exposure normal</i>	<i>Developer</i>		<i>Development time at 65° F., in seconds</i>
		<i>A</i>	<i>B</i>	
		<i>Ounces Drams</i>		
Black	Normal	1		20
Warm black	N. $\times 1\frac{1}{2}$	1	+ 2	30
Brown	N. $\times 2$	1	+ 2	40
Warm sepia	N. $\times 3$	1	+ 3 $\frac{1}{4}$	50
Purple	N. $\times 4$	1	+ 4	60
Red	N. $\times 6$	1	+ 5	70

The relation between the time of development and the temperature is an important factor in securing these tones, and the difficulty of maintaining constant temperatures is obviated by using the factorial system of development. The factor for the above developer is 3. If the image appears in 10 seconds, the total time of development should be 30 seconds (3×10).

The appearance of the slide during development is more deceptive when working for colors than when making cold black slides, because the image is less on the surface and more buried in the film. For this reason, slides are better developed by time and temperature or by the factorial system, than by inspection. Slides made by these methods will not only be uniform in color, but correct in gradation. If the results are too dense or too thin, the exposure has been too long or too short, and another slide should be made. If the development is prolonged or shortened to compensate for errors in exposure, the gradation will be altered and probably the quality of the slide will be poor.

PHYSICAL DEVELOPMENT.—Softer slides from harsh negatives, greater transparency in the shadows and a unique blue-black tone which is well adapted to sulphide toning, are the advantages claimed for this method of development. Fresh chemicals must be used and absolute chemical cleanliness must be maintained. About double the normal exposure must be given. The metol formula suggested by Dr. Mees is:

<i>Solution A</i>		
Metol	77 gr.	5 g
Citric acid	77 gr.	5 g
Acetic acid	1 oz.	25 cc
Distilled water to make	16 oz.	500 cc
<i>Solution B</i>		
Silver nitrate	1 oz.	10 g
Water	10 oz.	100 cc

For use add 50 minims of solution B to 1 ounce of solution A, and rock the tray constantly during development. Trays should be of glass, bakelite, stainless steel, or chromium plate, as the silver is deposited upon other substances, weakening the solution. All utensils used in this process should be washed in dilute nitric acid and rinsed before use, to make them chemically clean.

THIOCARBAMIDE DIRECT DEVELOPMENT. — The colors and quality of the image obtained with this developer, also suggested by Dr. Mees, are good. The colors range from magenta red through purple to blueish gray and neutral gray. The warmer colors necessitate a longer exposure as well as modification of the developer. The stock solutions are:

<i>Solution A</i>		
Metol	77 gr.	10 g
Hydroquinone	169 gr.	22 g
Sodium sulphite (crystals)	1 oz., 330 gr.	100 g
Sodium carbonate (crystals)	1 oz., 330 gr.	100 g
Water to make	32 oz.	2000 cc
<i>Solution B</i>		
Ammonium carbonate	384 gr.	50 g
Ammonium bromide	384 gr.	50 g
Water to make	8 oz.	500 cc
<i>Solution C</i>		
Thiocarbamide	30 gr.	3 g
Ammonium bromide	10 gr.	1 g
Water to make	8 oz.	400 cc

The color of the slide changes very rapidly in development and it cannot easily be followed in the rather dim illumination of the darkroom. The effect that is secured depends to some extent on the type of negative that is used in making the slide and the only way to make the results identical when using negatives of varying contrast is to make the negatives as much alike as possible by intensification or reduction. Factorial development may be used to advantage, using a factor of 6 with a temperature of 70° F. (21° C.) which will allow time for control. With higher temperature and a lower factor greater density is secured. The sensitiveness of this developer to temperature changes makes it difficult to get identical results. Uniform temperature can be maintained by using a water-bath.

Modification of the developer solutions for different tones is as follows:

A 14 parts, B 1 part and C 1 part gives warm, brown tones.

A 12 parts, B 3 parts and C 1 part gives blue-gray tones.

A 10 parts, B 5 parts and C 1 part gives warm black tones.

Very pleasing brown and sepia tones are secured by direct development under inspection by the method of desensitizing suggested by Cuisinier.

WARM TONES BY DESENSITIZING

Sodium sulphite	307 gr.	40 g
Potassium carbonate	192 gr.	25 g
Potassium bromide	23 gr.	3 g
Hydroquinone	77 gr.	10 g
Warm water	16 oz.	1000 cc

Use the above stock solution, 10 parts, with 1 part of a 1 to 1000 solution of phenosafranine, and water to make up to 300 parts. Any other suitable de-

sensitizer may be substituted. Development is started with the ordinary dark-room light, but after 2 or 3 minutes it will be safe to use a 10- or 15-watt lamp behind a translucent screen by which to judge the development. Complete development takes from 6 to 8 minutes.

REDUCING LANTERN SLIDES. — Slides that are too dense may be reduced with the ferricyanide and hypo, Farmer's reducer. Applying a solution of ferricyanide to the slide fresh from the fixing bath, as is sometimes advocated, is liable to cause stains, so the slide should be fixed and thoroughly washed and then the reducer applied for only a few seconds and immediately rinsed off. This may be repeated if further reduction is needed, but care must be taken not to carry the reduction too far. This reducer works fairly rapidly and if it is allowed to act too long it will destroy the delicate gradations in the highlights. It may also affect the color of the slide. Many slides that are slightly fogged may be improved considerably by a very brief treatment with this reducer to remove the fog and make the slide more brilliant. Local reduction is possible by applying the reducer to those parts only where it is needed, by means of a wad of cotton. Frequent rinsing under the faucet will prevent the reducer from spreading to parts where it is not needed.

FIXING. — Because the slides when projected in the lantern are sometimes subjected to considerable heat, especially when for some reason a slide is held on the screen longer than usual, they are best fixed in an acid-hypo-alum bath, such as the Eastman F-1.

ACID-HARDENING FIXING BATH (Eastman F-1)

Hypo	16 oz.	480 g
Water	64 oz.	2000 cc

Dissolve the hypo completely; then add the entire quantity of the following hardening solution:

Water, about 125° F. (52° C.)	5 oz.	160 cc
Sodium sulphite	1 oz.	30 g
Acetic acid (28 per cent pure)	3 fluid oz.	96 cc
Potassium alum	1 oz.	30 g

To mix the hardener, dissolve the chemicals in the order named. The sulphite should be dissolved completely before adding the acetic acid. After the sulphite-acid solution has been mixed thoroughly, add the potassium alum with constant stirring. Cool the hardener and add it slowly to the cool hypo solution while stirring the latter rapidly.

This bath hardens the emulsion so that it will not melt under any heat to which it is likely to be subjected.

If the slide is to be hand colored with water colors, hardening the emulsion may make it difficult to apply the color, and in such cases many workers dispense with the insurance against heat that is furnished by the use of the alum

bath, and fix in a plain hypo bath or in one acidulated by the addition of potassium metabisulphite.

ACID FIXING BATH

Hypo	3½ oz.	185 g
Water	10 oz.	625 cc

Dissolve and add:

Potassium metabisulphite	28 gr.	4 g
Water	6 oz.	375 cc

WASHING AND DRYING. — After fixation the slides are washed for ½ hour in rapidly running water. After washing, the face of the slide should be carefully wiped with a pledget of cotton under water to remove any specks or scum that it may have picked up during the washing. The slides are dried while held on edge in a rack, in a current of dry air, taking care that there is no dust in the air, as any particle of dust on a lantern slide makes a sizeable blemish on the projected picture.

TONING LANTERN SLIDES. — In addition to the tones that may be obtained by overexposure and restrained development, the color of a developed lantern slide may be modified in very much the same way as a print on bromide or chloride paper. Many of the formulas given for toning bromide prints will work well with lantern slides and there are some that can be used for slides that are not very suitable for prints because they would stain the paper base.

These toning processes often intensify or reduce density and contrasts and therefore a suitable method of toning may often be selected to improve a slide that is too thin or too dense or one that has too much or too little contrast, and a slide that is made for toning by any special process must be of such a character that the alteration effected by the toning process will be allowed for. A slide cannot be judged except by actual projection on the screen.

Sepia Tones (Eastman T-10). —

Solution A

Potassium ferricyanide	½ oz.	30 g
Potassium bromide	¼ oz.	15 g
Water to make	16 oz.	1000 cc

Solution B

Sodium sulphide (crystals)	20 gr.	2.8 g
Water to make	16 oz.	1000 cc

If fused sulphide is used instead of crystals, use only one-third as much. If the sulphide solution is boiled for a few minutes, any iron impurities there may be in it will clot and settle to the bottom of the container. Bleach the slide in solution A for 5 minutes, wash it for 5 minutes, and then redevelop it in solution B, which will take about 2 minutes. Then wash for 15 minutes. A thin slide will acquire a warm brown tone by this method of toning, a

slide that has been very fully developed will have a colder tone. A little hypo added to solution B with a slide that is just a little bit too dense will reduce the density and improve the transparency of the slide.

Blue Tones. — A reliable method to obtain a blue tone is as follows:

<i>Solution A</i>		
Sulphocyanide of ammonium	200 gr.	13 g
Water	32 oz.	1000 cc
Carbonate of soda (granular)	2 gr.	0.13 g
<i>Solution B</i>		
Chloride of gold	15 gr.	1 g
Water	1 oz.	30 cc

For use take 2 ounces of solution A and add to it 4 drops of solution B. This will make enough solution to tone one slide to a perfect blue color. The toning solution should be used at a temperature of 72° to 76° F. (22° to 25° C.). If the solution is colder than this the toning will proceed too slowly and the results will be unsatisfactory. This toning process does not perceptibly increase the density of the slides.

Green Tones. — The following treatment is suitable for slides that are a little too thin, as the process increases density to a slight extent. Make up the following solutions:

<i>Solution A</i>		
Oxalate of iron	20 gr.	1.3 g
Ferricyanide of potassium	15 gr.	1 g
Water	32 oz.	1000 cc
<i>Solution B</i>		
Chromate of potassium	5 gr.	0.3 g
Water	16 oz.	500 cc

Immerse the slide in solution A. In this solution the color of the slide will turn to a dark blue. The slide should then be placed in solution B for a minute and dried. When dry, the slide will be bright green.

Red Tones. — The so-called Bartolozzi red tone may be obtained as follows:

<i>Solution A</i>		
Ferrocyanide of potassium (yellow prussiate)	15 gr.	1 g
Water	16 oz.	500 cc
<i>Solution B</i>		
Uranium nitrate	30 gr.	2 g
Sulphocyanide of ammonia	150 gr.	10 g
Citric acid	30 gr.	2 g
Water	16 oz.	500 cc

For use take equal parts of solutions A and B. Soak the slide for 10 minutes in clean water and then immerse it in the mixture of A and B solutions in which it will quickly assume a beautiful red chalk color. If the whites are stained, place the slide for 1 minute in the following solution:

Sodium carbonate	15 gr.	1 g
Water	32 oz.	1000 cc

Then wash the slide thoroughly.

DYE TONING. — In this process the image is first bleached into a mordant that will combine with a dyestuff to form an insoluble compound of the color in direct proportion to the original deposit of silver. In this respect the process differs from simple dyeing which would give an even tone over the whole slide, introducing as much color into the highlights as into the other parts of the picture. The image may be bleached by changing it to silver iodide in the following solution:

Iodine	115 gr.	15 g
Potassium iodide	384 gr.	50 g
Glacial acetic acid	192 minims	25 cc
Distilled water to make	16 oz.	1000 cc

Dissolve the iodide in about 100 cc of the water and then stir in the brown iodine flakes.

Cupric chloride will also bleach. Make a solution as follows:

Cupric sulphate	384 gr.	50 g
Sodium chloride (table salt)	154 gr.	20 g
Water	16 oz.	1000 cc

A 2 per cent solution of potassium iodide changes the bleached image to silver iodide. Or use:

Cupric sulphate	384 gr.	50 g
Water	8 oz.	500 cc

Dissolve and add:

Potassium iodide	256 gr.	33 g
Water	1 oz., 288 minims	100 cc

The heavy precipitate is then dissolved in an ammonia solution and the total bulk is made up to 16 ounces (1000 cc).

Iodine stain on the gelatin can be removed by means of a 40 per cent solution of sodium bisulphite which can be prepared as follows:

Sodium sulphite	11 oz., 296 gr.	500 g
Water	16 oz.	750 cc

Stir well and add gradually with stirring:

Sulphuric acid	2 oz., 48 minims	100 cc
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After bleaching and decolorizing, the deposit on the slide will selectively take up certain dye stuffs classed as "basic dyes." Some of these basic dyes are:

Safranine A	red
Fuchsin	red
Rhodamine 36 or 66	red
Janus Red B	red
Pyronin G	red
Chrysoidin 3 R	orange
Auramin	yellow
Vesuvium	yellow
Chrysoidin Y	yellow
Thioflavin	yellow
Safranine Y	yellow
Victoria green	green
Methylene green	green
Malachite green	green
Methylene blue BB	blue
Victoria blue B	blue
Night blue	blue
Thionine blue	blue
Mixed methylene blue and green	blue
Methyl violet	violet

All these dyes with the exception of the methyl violet should be used in the proportion of 1.5 to 2 parts of the dye to 1000 parts of water. The weaker solution gives more brilliancy in the tones. Methyl violet should be used at one-half the above strength. Mix the dye with hot water and filter. Add a little glacial acetic acid and dilute to the required bulk with cold water. Metallic impurities must be avoided and therefore it is better to use glass trays when toning.

This method of dye toning sometimes intensifies the slides, so a slide that is inclined to be too dense should not be so treated. If the color is too intense, it may be reduced by immersing the slide in a 2 per cent solution of ammonia. If the slide, after dye toning, is too dense, its transparency can be increased by reducing the silver iodide in a special hypo bath made up as follows:

Hypo	2 oz., 277 gr.	150 g
Sodium acetate	384 gr.	50 g
Tannin	384 gr.	50 g
Water	16 oz.	1000 cc

Remove the dyed slide from this bath as soon as the desired transparency is attained and wash thoroughly.

In another mordanting process, potassium ferricyanide is used to produce metallic ferrocyanide which will hold a dye stain. In general, these ferricyanide mixtures must be protected from light and the potassium ferricyanide that is used must be pure and free from any yellow coating.

COPPER MORDANTING. — Copper ferrocyanide is the mordant produced:

Cupric sulphate	154 gr.	20 g
Potassium ferricyanide	115 gr.	15 g
Potassium citrate	2 oz., 47 gr.	120 g
Ammonium carbonate	77 gr.	10 g
Water to make	16 oz.	1000 cc

Use cold water in making up this solution; hot water will decompose the ammonium carbonate. Bleach the slides in this solution until no trace of a black image is left. This may take 15 or 20 minutes. Then wash the slides and immerse them in a 20 per cent solution of hypo and wash. The slides may then be colored in the dye bath as described above.

COPPER SULPHOCYANIDE MORDANT (Christensen).— This is a very satisfactory process as modified by Lumière:

<i>Solution A</i>		
Cupric sulphate	200 gr.	26 g
Potassium citrate	461 gr.	60 g
Glacial acetic acid	$\frac{1}{2}$ oz.	30 cc
Water	12 oz.	750 cc
<i>Solution B</i>		
Ammonium sulphocyanide	154 gr.	20 g
Water	4 oz.	250 cc

Just before use, mix 1 part of solution A with 3 parts of solution B. The image, after it is bleached, will be a dirty gray. It is essential to use only pure chemicals. The solution, when properly mixed, will be a clear blue-green color with no turbidity. After bleaching and washing, the slide may be colored in the dye toning solution as above. If the highlights are stained, the stain may be removed in:

Potassium permanganate	3 gr.	0.4 g
Sulphuric acid (concentrated)	38 minims	5 cc
Water	16 oz.	1000 cc

Or a 2 per cent solution of ammonia may be used to remove stain.

VANADIUM MORDANT.— The vanadium toning bath for green tones on bromide paper (see page 184) will produce a bleached image that is amenable to dye toning if the ferric oxalate is omitted. It is not often necessary to fix out the silver from the bleached image. After washing, the dye toning bath is applied as usual.

URANIUM MORDANT.—

Uranium (uranyl) nitrate	57 gr.	8 g
Oxalic acid	28.5 gr.	4 g
Potassium ferricyanide	28.5 gr.	4 g
Water to make	16 oz.	1000 cc

Use 1 part of the above solution to 4 parts of water. If properly mixed, the solution will be a clear, light yellow color. The nitrate must be free from acid impurities.

Bleach the image to a light chocolate color, which usually takes about 2 minutes. If the bleaching is stopped at this stage, the dye toning will be effective but the temperature should not be above 70° F. (21° C.). Two of the dye solutions may be mixed together to give a different color, or the two solutions may be used in succession.

BINDING. — Lantern slides are bound with a cover glass, with a mask between the glass and the slide, to mask out all except the part of the slide which is desired to be shown. The cover glass and the slide with the included glass are held together by pasting a strip of gummed tape around the edges. It is better practice to have this binding strip continuous than to cut it at the corners, which may allow a small opening through which dust can enter. The strips are so thin that they can be folded down on the corners so flat that they will not interfere with the handling of the slide in the carrier.

The slides should be dry and absolutely free from moisture before they are bound up with the cover glass. It is a good plan to heat them by holding them near a radiator or other source of heat just before binding. Otherwise, the moisture in the emulsion will be condensed by the heat of the lantern during projection and show as spots upon the picture on the screen. If moisture in a slide is heated enough by the heat from the projection light, steam will be generated inside the slide and it will crack either the slide or the cover glass.

The picture area is usually masked by a cut-out paper mask included between the slide and the cover glass. The Society of Motion Picture Engineers has adopted the size $2\frac{1}{4}$ by 3 inches as a standard for the opening in the mask, so that slides can be shown upon a screen interchangeably with motion pictures, both having the proportion of 3 to 4, but in private practice this size is often not adhered to and slides are masked to any size or shape best suited to the individual picture. There is, however, an advantage in having most of the pictures appear the same size upon the screen, as constant changes in size are tiresome to an audience. Masks were formerly cut with rounded corners, which was an advantage in the days when lenses were frequently used which did not quite cover the plate and showed a falling off on the edges. But later models of stereopticons cover the plates fully and masks are usually cut with square corners.

SPOTTING. — Slides must be placed in the stereopticon upside down and with the cover glass next to the light. To indicate the correct position, it is usual to place guide marks upon the mask. The American standard practice is to place a white *spot* of gummed paper at the lower left-hand corner of the picture as it is viewed in its proper position. In Europe the spot is placed in the lower right corner, while in England a spot is placed in each of the two *upper* corners. By the American and European methods, the slide is placed in the carrier so that the spot is at the top, while by the English method the spots must be at the bottom. In any case the slides are put into the lantern so that the spots are away from the screen if projecting on to an opaque screen, but on the side towards the screen if it is translucent and projection is *through* the screen.

SCREENS. — Screens are usually opaque with a reflecting surface upon which the picture is projected by a stereopticon located behind and above the

audience, but translucent screens are used in some situations with the stereopticon located behind the screen.

Translucent screens are made of fine muslin covered with gelatin or cellulose varnish. They are generally used for daylight projection when it is not possible to have the operating room in complete darkness. Projection is from the rear and it is easier to exclude extraneous light from the screen than it is when projecting the full length of a room. This results in more brilliant images under adverse lighting conditions. For a permanent installation, groundglass makes an ideal translucent screen but on account of its expense, and danger of breakage, it is not generally used. Tracing cloth is sometimes used. Wet cotton cloth makes a very good translucent screen, the only difficulty being to keep it wet during operations. If the time is not too long, this can be accomplished by mixing 10 per cent glycerin or calcium chloride in the water.

A translucent screen has to be so opaque that it will not show the projecting lens as a flare spot through the screen. For economy of operating space, and to minimize the effect of stray light, very short focus lenses are used when projecting upon a translucent screen.

Opaque screens are made in a great variety of surfaces. Permanent installations usually consist of wood or cloth painted with a flat white paint, or metalized. The simplest form of portable screen is a sheet of well-sized cotton cloth, stretched until free from wrinkles. About the only thing to recommend this is its easy portability. If the cloth is painted with a flat white paint, its reflecting power is greatly increased but it cannot then be folded and must be rolled for transportation. Beaded screens are commercially furnished on rollers and their reflecting surface is so great that they give very brilliant images if seen at a narrow angle. At wider angles of viewing the illumination falls off rapidly. Glass screens yellow with age, and if they are used to show color slides, this introduced color degrades the color of the slides and the screen has to be replaced with a new one every year or so, the time depending upon the amount of use.

A good formula for an aluminum-coated opaque screen is:

Warm water	20 oz.	1000 cc
Slaked lime	260 gr.	30 g
Casein	300 gr.	35 g
Sodium silicate	90 gr.	10 g

When thoroughly mixed add:

Whiting	175 gr.	20 g
Impalpable aluminum powder	175 gr.	20 g

STEREOPTICONS. — The simplest stereopticon is a machine that handles a single slide at a time. The carrier holds two slides, one in front of the lens, and the other beside it in readiness to follow on the screen. Operation of a sliding carriage removes the slide that is being projected and substitutes the

other in front of the lens. As the effect of one slide going off the screen and the other coming on is somewhat confusing, some operators screen the lens at the moment of change. This results in an alternation of brilliant image and total darkness on the screen, which is very tiresome to the eyes of the audience, especially during a long lecture, and the method of momentary confusion, which need not exceed half a second, is usually preferred.

The double-dissolving stereopticon is really two complete stereopticons with matched lenses which alternate in projecting slides upon the screen. In one type of machine the transition between slides is made by a diaphragm over each lens so coupled that one diaphragm gradually closes as the other opens. The picture on the screen fades with the diminishing light while the other increases until the second picture entirely supplants the first. The same effect is secured in other models by having the projection lights controlled by rheostats so coupled that one light increases as the other diminishes. Double-dissolving stereopticons are easy on the eyes and are capable of producing beautiful effects, but they are slower to operate than the single machines.

Cooling devices to protect slides from heat while being projected are seldom considered necessary if the lamphouse of the stereopticon is provided with proper ventilation, but protection is sometimes needed when slides are used for instruction and have to be held on the screen longer than normal times. The best protection is a sheet of heat-absorbing glass between the slide and the light source. Water cells are a nuisance as the water usually gets to the boiling point during a long lecture and the movement of the water can be seen distractingly upon the screen. Electric fans incorporated in the stereopticon, however silent at first, become noisy after a little use and are a constant source of annoyance, both to the lecturer and the audience.

PROJECTION. — To find the focal length of lens necessary to get a certain sized image at a given distance, first find the ratio between the slide and the size of the image desired. For example, if the width of the desired image is 120 inches and the width of the slide is 3 inches, the ratio is 40. A $40\times$ enlargement will be formed at a distance of $40 + 1$ multiplied by the focal length of the lens. If the fixed distance is, say, 328 inches, the focal length of the projection lens must be $328 \div 41 = 8$ inches.

$$\text{Focal length} = (\text{Distance}) \div (\text{Ratio} + 1).$$

To calculate the necessary distance for a lens of given focal length to fill a screen of given width, find the ratio, add 1, and multiply by the focal length.

$$\text{Distance} = (\text{Ratio} + 1) \times (\text{Focal length}).$$

To find the size of the image that will be produced by a lens of given focal length at a given distance, divide the distance by the focal length of the lens and subtract 1 from the result. Thus, in the above problem, with an 8-inch lens at 328 inches from the screen, $328 \div 8 = 41$. Subtracting 1 from 41 leaves 40 which is the ratio between the slide and the image.

$$\text{Ratio} = (\text{Distance}) \div (\text{Focal length}) - 1.$$

HAND COLORING. — Transparent water color and, to a lesser degree, transparent oil color are used to color lantern slides. The pigment increases the over-all density of the slide, which must be made thinner than usual if it is to be colored. If the slides have been fixed in a hardening bath they are likely to repel the water color, but this tendency can be largely overcome by first soaking the slides in water to which a few drops of ammonia have been added. In coloring, the slide must be supported upon a glass plate and transilluminated by a soft light which should approximate as closely as possible the light by which the slide will be projected. Hand coloring is a delicate operation which must be done under a magnifying glass if fine detail is to be preserved, as any slight overlapping of colors will give a very unpleasant effect when greatly magnified upon the screen. Success in the work depends upon the painstaking care with which it is performed and upon the operator's knowledge and appreciation of color, which must be comparable to that of any other artist. A competent worker can produce results esthetically far superior to anything that can be secured by mechanical processes of color photography, but of course at a far greater cost.

DIAGRAMS. — Diagrams on tracing cloth can be printed directly by contact upon lantern slides. The negative is often used for projection as it shows white lines upon a black ground, which combination is less tiring to the eye than the broad expanse of glaring white afforded by a positive of the same subject. Line subjects should be strongly developed and if necessary, slightly reduced with Farmer's reducer so that there will be no tones except black and white upon the plate.

Unexposed lantern slide plates may be fixed out, washed and dried, leaving a clear gelatin coating on the glass on which the diagram may be drawn with an opaque drawing ink. Special glass or china marking pencils may be used on plain cover glasses.

To give white lines on a dark background, coat the slide with the following mixture:

Canada balsam	4 parts
Pure turpentine	8 parts
Liquid glue	1 to 2 parts

Mix thoroughly and add as much lampblack as will give it the consistency of an ointment. Coat the glass evenly with this mixture, using a badger hair softener.

Or use the following mixture:

Syrian asphalt	50 parts
Yellow Venice turpentine	10 to 12 parts
Linseed oil or varnish	15 parts
Pure turpentine	15 parts

Melt the asphalt and Venice turpentine in the turpentine by heat and add the linseed oil with continual stirring. Then add enough lampblack, as before, to make the mixture as thick as an ointment. Coat glass with this mixture until it is opaque and allow it to dry, then rub over it a little lampblack rubbed up with gum water. This will be repelled at first but with continued working, it will adhere.

To make a diagram or a slide showing writing or lettering, use a large darning needle for fine lines, scraping right through the black coating to the bare glass. Broader surfaces may be scraped out with a knife or an etching tool.

KEEPING LANTERN SLIDES IN ORDER. — When the slides of a lecture have been arranged in proper order in the carrying case, with a white pencil rule a line diagonally from top to bottom on the edges of the slides. Any slide that is thereafter out of sequence or inverted will show a break in the continuity of the line.

CHAPTER XXI

COPYING

CAMERAS FOR COPYING. — Any type of camera may be used for copying provided it has sufficient bellows extension. A studio camera or a view camera which focuses from either front or back and has interchangeable lenses is the most convenient.

Some means should be provided for keeping the camera trued up with the copy-board. This is usually accomplished by building a track upon which both the camera and the copy-board slide back and forth for adjusting the size of the image but without getting any of the parts out of parallel. The lens should usually be kept exactly centered on the copy-board and the copy so placed that it will photograph with the lens in this position so that the lens will be sure to cover all of the negative. It is usually more convenient to focus from the back, moving the copy-board nearer to or further away from the lens to adjust the size of the image. When working in districts subject to much vibration, it is sometimes necessary to suspend the camera on springs to avoid vibration.

When copying a drawing or sketch on white paper, reflections from the inner surfaces of the bellows are sometimes troublesome. These can largely be prevented by putting a blackened card with a suitable rectangular opening in one of the folds of the bellows to cut off these reflections from the negative. A lens shade should always be used. For this purpose, an old camera bellows affixed in front of the lens is very efficient and convenient, as its length is easily altered to suit different requirements.

The usual run of work is more easily copied with the camera in a horizontal position, but situations often arise in which a vertical position of the camera is necessary, as in copying coins or other objects not easily suspended, or in copying objects in a water bath. While makeshift work can be done with a tilting head on a tripod, this work is difficult, and time-consuming, and if any volume of it is to be attempted, a more substantial and more easily operated arrangement should be made from iron pipe.

LENSES FOR COPYING. — Although a rectilinear lens can be used for copying, it is not as convenient as an anastigmat lens which has a flat field, gives equally good definition over the entire surface of the negative and can be used at any aperture necessary to regulate the exposure. A rapid rectilinear not being corrected for astigmatism, cannot give the definition and crisp brilliancy of an anastigmat. The greater speed of an anastigmat shortens the time of

exposure and thus reduces the possibility of vibration. For the very finest results, especially when copying a colored original, apochromatic lenses must be used.

The focal length of the lens needs only to be long enough to cover the negative at the greatest reduction which will be made. This means that a lens may be used which has a shorter focal length than would be necessary to cover the negative at infinity focus. Lenses of longer focal length may be used without detriment, but the shorter the focal length of the lens the greater the economy in working space. If the lens is too short, it may be impractical because copying at near or greater than original size may bring the lens so close to the copy-board as to lead to difficulty in getting even lighting. Lenses of different focal length should be available for different purposes.

FOCUSING. — For critical focusing, a focusing magnifier that rests firmly on the focusing screen should be used, rather than a reading glass or similar magnifier which is used at variable distances. The focusing magnifier should be properly adjusted to the eye of the operator by focusing it sharply on a fine hairline on the ground side of the groundglass, and then locked in that position. For very fine focusing, greater visibility is secured by smearing a little glycerin on the groundglass. Focusing to scale can be accomplished by placing a plainly graduated ruler on the copy-board and measuring the image on the groundglass, after which the copy is substituted for the ruler. If much of this work is to be done, it is convenient to mark upon the base-board the position of the lens, or some easily visible part of the camera, and the position of the copy-board, for various scales of reduction.

The groundglass of the camera and also the copy-board should be marked with diagonal lines from corner to corner so that the centers will be indicated by the point of intersection of these lines. By this method, the center of the copy-board and the center of the negative can be easily lined up.

ILLUMINATION. — It is essential that the whole of the copy be evenly illuminated, and for this purpose lights must be placed upon both sides of the copy and sometimes, if the object is large, upon all four sides of the copy-board. The lamps should be placed at such an angle to the copy-board that their light is not reflected back into the lens. This is easily accomplished by remembering that the angle of reflection is equal to the angle of incidence. Frosted bulbs should always be used to avoid as much glare as possible. Objects that give troublesome reflections, such as pictures which must be copied under glass, are best copied by polarized light with a polarizing screen over the lens. Failing this, the copy may sometimes have to be tilted out of plumb to avoid reflections.

For some subjects where glare is prevalent, diffused daylight is easier to handle than artificial light. This is often the case with large oil paintings which cannot be handled with the usual apparatus.

In using filters, allowance must be made for the difference in the effect when using artificial light or daylight. The preponderance of red in artificial light is about equal to the effect of a K1 filter, so that with artificial light a K1 filter is often sufficient in situations that would require a K2 filter in daylight.

COPYING DOCUMENTS. — Direct contact prints from the original can sometimes be made upon bromide paper, showing white lines on a dark background. This method is satisfactory for many purposes if the original is transparent enough, and it obviates the necessity of making a negative and a subsequent print. For copying etchings, engravings, line drawings, and black-and-white paintings, process emulsions give the best results. For brown or red on white originals, orthochromatic emulsions without filters give good results. Colored originals must be photographed upon panchromatic emulsions with suitable filters.

COPYING PRINTS. — Photographic prints are best copied upon process or orthochromatic emulsions. If they are soiled, they can be cleaned with art gum, water, or alcohol, except that prints upon collodio-chloride papers must not be cleaned with alcohol because the emulsion is soluble in it.

If prints are so weak and thin that a usable negative cannot be made from them, the printing image can be built up by making as good a negative as possible, and then illuminating it by transmitted light and copying it in the camera to make a positive. The positive is then transilluminated and copied again to make a new negative. By each of these steps, some additional deposit of silver is gained and the final negative is likely to have a printable density.

Prints that are so dark that very little detail shows upon the surface are often found to have more detail buried in the emulsion. Such prints can be copied by transillumination for part of the exposure. Give about two-thirds of the exposure with the print illuminated from the front as usual, and complete the exposure with light shining through from the back of the print.

A print with grain or texture so pronounced as to make it troublesome, can be copied by covering the surface with glycerin and then sandwiching it between two glass plates and clamping it in a printing frame. After copying, the glycerin can be washed off with water without harm to the print. This process is particularly efficacious in getting copies from old albumen prints whose glazed surface is likely to be covered with tiny cracks.

Faded prints can be brightened up by copying them upon panchromatic film while using a G or an A filter over the lens.

Prints upon platinum paper are hard to copy and good results are not obtained by the glycerin treatment. The best procedure is to attach the print by rubber cement to a sheet of glass and place it under water in a tray and photograph it vertically. Avoid any friction in cleaning the platinum print as the surface is easily abraded.

HALFTONES. — It is sometimes desirable to copy a print from a halftone without showing the screen which covers its entire surface. The best compromise is to use a soft-focus lens or other diffusing medium which can be so focused that the screen will disappear, although the image will not be perfectly sharp.

BOOKS. — Some book papers are so thin and translucent that the printing is likely to show through from the back of the page. This can be largely remedied by backing the page up with a sheet of black paper.

COLORS ORIGINALS usually present no difficulty if the work is done upon a panchromatic emulsion with the use of a K2 filter.

BLUE PRINTS are copied upon panchromatic film with the use of an A, F, or B filter to make the blue record dark enough to give sufficient contrast with the white lines. To get rid of the ruling, when copying diagrams upon paper ruled in blue, use a color-blind emulsion or a panchromatic emulsion with a C filter.

TYPEWRITING. — Blue lettering on white paper is given sufficient contrast by the use of panchromatic emulsions and an A, F, or B filter. When the type-writing is in red and black, and it is desired to make it all appear black, use a color-blind emulsion and no filter. If it is desired to show the difference between the red and black, use a panchromatic emulsion and the red F filter. For copying black lettering on pink or red paper, use a panchromatic emulsion and an A or F filter.

UNFIXED PRINTS. — Although it is unethical to make a copy negative from another photographer's proof, it is sometimes necessary to do this on account of loss or injury to the original negative. These prints are of a reddish color and are copied upon a panchromatic emulsion with an A filter. The principal difficulty is that the original print will darken upon exposure to light and this darkening may be so rapid as to occur during the copying, and spoil the result. To prevent this, the print is protected by a colored screen. Take a glass plate of suitable size, and in the ordinary hypo bath fix out all the silver, without exposing the plate to light. The remaining emulsion is stained by immersion in a saturated solution of bichromate of potassium. After drying, this plate is bound up in contact with the face of the print, which it protects from the action of light while it is being copied.

DAGUERREOTYPES. — The surface of a daguerreotype is very delicate and it is usually bound up under glass. If it presents a faded appearance this is very often caused by discoloration of the glass. To copy, remove the glass and photograph upon an ordinary emulsion unless the daguerreotype has been tinted, in which case a panchromatic emulsion and a K2 filter should be used. To get a bright and snappy result, all reflections from the polished surface of the daguerreotype must be avoided, and it is often necessary to do this under diffused daylight. If artificial light must be used, it is sometimes necessary to tilt the daguerreotype slightly out of plumb to avoid all the reflections.

The standard copying procedure is to make a tunnel of black velvet and place the daguerreotype at one end, introducing the lens at the other. An opening in the side near the daguerreotype is made to let in the light. This strong side lighting often emphasizes the buffing marks upon the daguerreotype, but this difficulty can be overcome by revolving the daguerreotype so that the light strikes these marks at a different angle.

Another method is to set the daguerreotype up opposite a screen of black velvet in which there is a hole for the lens. In either case, the idea is to have nothing but black surfaces that the daguerreotype can reflect.

FERROTYPES, or tintypes as they were commonly called, were sometimes mounted under glass, and sometimes varnished and mounted without the glass. The surface of old ferrotypes is likely to be covered with minute scratches. If the ferrotype has been varnished, these scratches can be avoided by the use of glycerin as recommended for prints. If the surface is unvarnished, glycerin should not be used as it is likely to injure the ferrotype, and the best that can be done is to remove the glass and carefully dust the surface with a soft brush. Use an ordinary emulsion unless the original is tinted, in which case use a panchromatic emulsion and a K2 filter.

AMBROTYPES are glass negatives bound up with a black velvet background. They can usually be removed from the mount, and prints made from them by projection as from an ordinary negative. If the ambrotype is varnished and yellow, it can be copied by transmitted light using the panchromatic emulsion and an A or G filter.

COINS AND MEDALS.—A little lampblack moist color rubbed on to the coin and rubbed off again, helps to throw the modeling into greater relief. Use an even light, coming from one direction only, and soften it with a diffusing screen. Coins and medals are best photographed against a background of black velvet. When it is desired to show both sides of a coin, two negatives can be made and put together without showing a line between them, if this background is used. Another way is to make casts of the coins and photograph the cast instead of the coin itself. Put some ordinary glue in a small receptacle such as a tin can cover and allow it to harden. Smear the coin with thin oil or melted butter and just before the glue has set, press the coin into it for its entire thickness so that the top of the coin is even with the surface of the glue. Leave it in this position until the glue has entirely hardened, when it can be easily removed. The surface of the mold, so formed, should be brushed lightly with kerosene and then filled with a thick paste of plaster of Paris, pressed in with a flexible blade or a spatula so that it completely fills all the lines of the mold. When the plaster has set, which takes only a few minutes, the cast is released from the mold by gently tapping it on the back. Before copying, the cast should be dusted over with a little powdered lampblack or graphite and then the surplus gently blown off. If both the obverse and reverse of a coin are shown together, it is customary to join them by two

straight lines to indicate that the two pictures are of the same object. This is easily accomplished by cutting narrow strips of white paper and placing both casts upon it, slightly separated, on the black velvet background. It is customary to show the obverse (head) side to the left. Copy upon a slow process emulsion, and develop to get crisp negatives.

When copying bright coins or other metal objects with polished surfaces, the glare and reflection can be cut down by gently dabbing the surface with putty.

DEVELOPMENT. — In general, copy negatives should be developed with the manufacturer's formula for the emulsion upon which they are made. For excessive contrast, as in copying line work, use a contrast developer (see page 60).

CHAPTER XXII

COLOR PHOTOGRAPHY

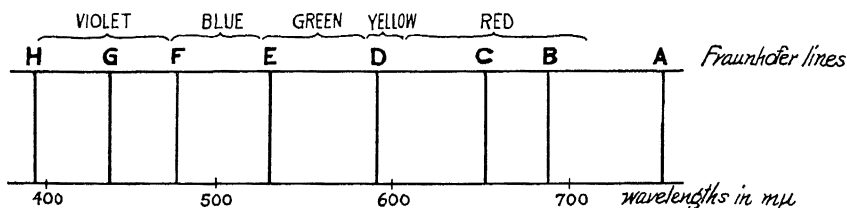
White light consists of an infinite number of colors blended into a combination so complete that it gives no impression of color. If this white light is broken up into its component parts, as can be done by passing it through a prism or, better, through a grating of parallel equidistant lines, which may be from 10,000 to 40,000 per inch, it will be found that each part consists of a different color. The colors so displayed form the visible spectrum, commonly seen in the rainbow. Many of these colors merge imperceptibly into each other, but they were long ago roughly divided into seven easily distinguished groups consisting of red, orange, yellow, green, blue, indigo, and violet. These divisions are purely arbitrary and confusing and are better forgotten by any serious worker in color. The spectrum divides naturally into three bands of equal extent, roughly classified as red, green, and blue. Within these three bands the colors merge imperceptibly, but between the blue and the green there is a narrow band of blue-green, and between the green and the red one of yellow, where the transition is rapid and easily visible. These are the divisions of the spectrum that are used in reproducing color.

Colors are of such infinite variety that it is impossible to name them all with any degree of accuracy, instead of which they are exactly designated by their wavelengths. Light, regardless of its color, travels in waves at the same speed, about 187,000 miles per second. These waves are identical in every respect except their length as measured from crest to crest of the wave. The optical sensation of color is produced solely by the difference in wavelength, every different wavelength causing a different color sensation to the eye. These wavelengths are so small that they are measured by special units, which are either Ångstrom Units (abbreviated A.U., or designated by the Greek letter λ , lambda) which are $1/10,000,000$ millimeter; or by millimicrons ($m\mu$) which are $1/1,000,000$ millimeter (millimicron = $1/1000$ micron (μ), which is $1/1000$ millimeter). The millimicron, equalling 10 Ångstrom Units, is the unit commonly used to measure the visible rays used in color photography, while the Ångstrom units are more generally used for the other similar, but invisible radiations which include the infra-red, ultra-violet, X-ray, cosmic rays, etc., that are of greater or lesser wavelength than the visible rays.

While it varies somewhat with the individual, visible radiations extend from wavelengths of about 400 $m\mu$ in the violet to 700 $m\mu$ in the red. Radiations less than 400 $m\mu$, down to about 350 $m\mu$, while not visible to the eye,

affect photographic emulsions. Radiations below 350 $m\mu$ are absorbed by glass, and hence not transmitted by the lens.

For less exact purposes, colors are designated by their positions in relation to the so-called Fraunhofer lines, which are the dark lines seen at definite locations in the solar spectrum, as shown on the accompanying diagram.



APPROXIMATE LOCATION OF PRINCIPAL COLORS AND FRAUNHOFER LINES

In 1861 Clerk Maxwell established experimentally the fact that all colors could be reproduced by suitable admixtures of the three groups of colors, red, green, and blue, into which the spectrum naturally divides. This fact had long been held as a theory, but from Clerk Maxwell's demonstration dates all successful photographic color work, using these three groups as primaries.

Theoretically, a mixture of the three wavelengths 640 $m\mu$ (red), 532 $m\mu$ (green), and 464 $m\mu$ (blue) should be most successful in imitating the remaining colors of nature, but because filters which excluded all but these wavelengths of light would result in a picture so dark as to be useless, broader bands which include wavelengths of light on each side of the dominant color of the band must be used for practical purposes. In practice, filters which in combination transmit all of the visible spectrum, give to the eye a sensation very close to that obtained by the use of the monochromatic lights indicated by theory.

Color is reproduced by either *additive* or *subtractive* processes. Additive processes work from darkness to light. Starting with one primary color, another is added, forming a combination of the two. If the third primary is added, the result will be white light because the three primary colors together comprise all the visible wavelengths of light. Subtractive processes start with white light and, by taking away the light of some of the wavelengths, leave the remaining colors which are only part of white light. Thus, if the primary groups of blue and green waves of light are blended, the result will be blue-green which contains all the wavelengths of light in the spectrum except those of the red group, and this color would be called an *additive* blue-green. The same color obtained by reflecting white light from a surface that absorbed the red only, while reflecting all other colors, would be termed a *subtractive* blue-green. This explains why filters are often negatively designated, as a filter that absorbs red light and passes only the complementary color, blue-green, would be called a minus-red filter.

By combining the three primary colors as in nature, we get white light, but by combining them in other proportions, either additively or subtractively, any color can be reproduced.

In the subtractive processes the final result is a set of superimposed positives which have been printed from negatives each of which records only one primary color. As the density of each *negative* represents the amount of that particular color that was in the original subject, the densities of the corresponding *positive* must represent not the presence, but the absence of that color. Hence the colors of the primaries used in subtractive processes are magenta, blue-green, and yellow, which are well known as the primaries used by artists and in the three-color halftone and other printing processes. These colors must be used for subtractive processes because they are complementary to the primaries for additive processes, magenta being complementary to the green, blue-green to the red, and yellow to blue. Complementary colors are two colors which in combination make white light. One color is complementary to another when it contains all the elements of white light which the other does not.

In actual practice the three colors used are not exactly complementary, but are near enough to give pleasing, if only approximately correct, results. Dyestuffs are available which will quite satisfactorily transmit one-third of the spectrum and hence give in combination a nearly faithful rendering of color by additive processes. But subtractive systems require dyestuffs that will transmit (or reflect) two-thirds of the spectrum, because each color used must (theoretically) be complementary to one of the primaries. No dyestuffs at this time of writing are available which will, over this wide band of the spectrum, absorb the rays that should be absorbed and transmit the rays that should be transmitted, with any great accuracy. The result is that by any purely mechanical process, colors are compromised, and while they may give pleasing effects that suggest the colors of the original, they are far from accurate. Only by the interposition of handwork, which is possible in some printing processes, can these errors be corrected.

The first attempts at reproducing color chemically were along the lines suggested by Prof. T. J. Seebeck of Jena who observed in 1810, long before the official discovery of photography, that if moistened silver chloride after being allowed to darken on paper were then exposed to different colors of light, the silver chloride would change to an approximation of the colors that had affected it. Becquerel in 1848 continued this investigation, and Niépce de Saint Victor exhibited color plates by this method, which was known as *Heliochromy*, at the Paris Exhibition of 1867. The process was laborious, exposures required an hour or more in full sunlight, and the results were fugitive, as there was no way of fixing them and their life was a matter of months.

The next attempts at color photography were along the line of the bleach-out processes in which a paper was coated with three primary-colored dyes

and after exposure, the unwanted color was bleached out. Beginning with the work of Charles Cros in 1881, this idea progressed to the Uto paper of Dr. Smith of Zurich in 1906 which required an exposure of 1 hour, although the time was reduced to 20 minutes for the improved process Utocolor which appeared in 1912.

The first really successful and permanent color photography was made by the additive processes. The earliest method was to make three color separation plates from which positives were made and superimposed by projection upon the same screen by three different lanterns, each using a different primary color of light. This method was so cumbersome and laborious and necessarily limited to still-life subjects from which the color separation negatives could be made at leisure, that it never attained any popularity, although within its limitations it produced very creditable results. The pioneer work on this method was largely done by Du Hauron in France and F. E. Ives in America, elaborating the principle demonstrated by Clerk Maxwell.

The next development was to get all the colors upon one plate, microscopically juxtaposed, so that when looked at by the eye at a normal distance, they appear to blend. There were two approaches to this problem. In one the colors were arranged in a regular pattern (*réseau*) by ruling in color, and in the other the colors were scattered at random (*mosaic*). In either case the colors had to be balanced so that in combination they produced white light. This method of handling color was first proposed by Du Hauron, but its first practical application was made by Prof. John Joly of Dublin University in 1894 by ruling alternate lines of red, green, and blue-violet upon a glass plate which was placed in contact with a panchromatic plate during exposure. The screen plate was removed and the panchromatic plate developed as a negative from which a lantern slide positive was made. Before projection, the lantern slide was bound in contact with a *viewing screen*, which differed from the *taking screen* only in the color of the ruled lines which were modified so that the result would be more brilliant when projected. This process was marketed from 1895 on, but was not very successful, largely because of the fugitive quality of the dyes employed, and on account of the coarseness of the screen which had sixty-seven lines of each color per inch, but the principle was retained in later, more successful, processes.

LUMIÈRE AUTOCHROMES AND FILMCOLOR. — The first commercially successful color process was the Lumière Autochrome, a mosaic screen plate, which was patented in 1903 and marketed in 1907. In this process a glass plate was covered with starch grains averaging about 0.015 mm in diameter, which were dyed orange-red, green, and blue, the interstices between the grains being filled with finely powdered carbon black to form a continuous surface, which was first covered with a waterproof varnish, and then with a panchromatic emulsion. Exposure was through the back of the plate so that no part of the emulsion was affected by light except selectively through one of the

colored starch grains which acted as screens. By one continuous process the plate was developed as a negative and then reversed into a positive so that the image upon projection appeared in natural color.

These plates had to be exposed with a special filter over the lens to compensate for the difference between visual and actinic light, which made them so slow that they could originally be used only for subjects in which no motion occurred. The process has been constantly improved, the size of the grains reduced, the speed greatly increased, the emulsion coated upon film (Lumière Filmcolor), and the filter dispensed with for daylight exposures so that instantaneous exposures can be made.

Lumière Filmcolor should be developed in the dark or with the use of a safelight covered with Virida paper which is supplied for the purpose, but to which the film should be exposed as little as possible. Glass trays are safest for use with this process. If enameled trays are used, they should be free from imperfections in the enamel or from rust spots. The temperature should be kept at 65° F. If higher than this, there is danger of frilling. The first development is in Metoquinone, which may be purchased in prepared form, or which may be mixed as follows.

METOQUINONE DEVELOPER

Stock Solution

Distilled water	35 oz.	1000 cc
Metoquinone (Quinomet)	$\frac{1}{2}$ oz.	15 g
Sodium sulphite	3 $\frac{1}{2}$ oz.	100 g
Ammonia, 22° B.	9 drams	32 cc
Potassium bromide	240 gr.	16 g

Heat two-thirds of the water to the boiling point and dissolve the Metoquinone in it. When thoroughly dissolved, add the other chemicals in the order given, adding the other third of the water and waiting until the solution cools before the ammonia is put in.

The working solution is made by diluting 1 part of the above stock solution with 4 parts of water.

The first development should take about 2 $\frac{1}{2}$ minutes at 65° F., or the factorial system may be employed, multiplying the time that it takes for the first appearance of the image (disregarding the sky) by a factor of 10 to compute the total time of development.

After the first development, rinse the film for about 1 minute in running water and then place it in the reversing solution.

BICHROMATE REVERSING SOLUTION

Water	35 oz.	1000 cc
Potassium bichromate	30 gr.	2 g
Sulphuric acid, C.P.	3 drams	10 cc

(Caution: add the acid to the water, and never the reverse.)

This bichromate bath should be used only once, but keeps well in solution if protected from the light, so that it can be made up in bulk and kept on hand for use. After its use the film should be washed until all stain disappears.

Danger of stain is avoided with the use of a permanganate reversing solution, but this will not keep unless prepared in two solutions.

PERMANGANATE REVERSING SOLUTION

Solution A

Water	17½ oz.	500 cc
Potassium permanganate	30 gr.	2 g

Solution B

Water	17½ oz.	500 cc
Sulphuric acid, C.P.	3 drams	10 cc

Mix in equal parts just before use.

As soon as the film is covered by either one of these reversing solutions, it is exposed to artificial light or to daylight, while the process continues. Reversal should be complete, which will take 3 or 4 minutes, and its progress can be watched under the bright light until all the color shows.

After reversal, rinse for about 40 seconds in running water, and then redevelop to finality in the first developer, until the white parts of the image turn completely black. Rinse for 2 or 3 minutes in running water, and place to dry without fixing, and the process is complete. After it is dry, the film should be varnished to protect it from injury, as it is very tender.

If the temperature is unavoidably high, instead of using the first developer over again for the second development, use the following:

REDEVELOPER

Water	16 oz.	500 cc
Sodium sulphite	½ oz.	15 g
Dianol	40 gr.	2½ g

After the second development, films that have been overexposed or overdeveloped may be brightened by intensification, preferably using the Chrome Intensifier supplied by Lumière. There is no remedy for underexposure.

AGFA SCREEN PLATES AND AGFACOLOR ULTRA PLATES are an additive process depending upon a coating of colored grains of gum arabic or resin varying from 0.003 to 0.02 mm upon a glass plate through which the exposure is made, similar to the method used in the Lumière Filmcolor. It is also developed, reversed, and redeveloped similarly to the Filmcolor. It is made only in Germany where it was marketed from 1912 on, and after 1919 largely exported to other countries. The process was originally quite slow, standard exposures in summer noonday sunlight being about 1 second at $f:8$, but the color and the speed were progressively improved, culminating in the Agfacolor Ultra plate which is used without a filter in daylight and has a Weston rating of 3.

This process should not be confused with the New Agfacolor process which is a subtractive process on film, described in another section of this chapter.

Processing must be done in total darkness or under an Agfa No. 108 green safelight.

Agfacolor Ultra plates may be developed in Agfa No. 96 Agfacolor developer, or the developer may be compounded as follows:

AGFACOLOR ULTRA DEVELOPER

Metol	48 gr.	3.3 g
Sodium sulphite	328 gr.	25 g
Hydroquinone	15 gr.	1 g
Potassium bromide	22 gr.	1.5 g
Ammonia, sp. gr. 0.91 or 25 per cent by weight	2 drams	7.5 g
Water to make	32 oz.	1000 cc

This solution should be filtered before use. Each plate should be developed in a fresh solution of the developer. About 2 ounces will develop a $3\frac{1}{4}$ by $4\frac{1}{4}$ inch plate. The temperature should not exceed 65° F., or frilling and pinholes may occur. Development of a correctly exposed plate will be complete in about 4 minutes at this temperature unless the plate has been desensitized, when it will take about 5 minutes.

PINAKRYPTOL YELLOW DESENSITIZER

Agfa Pinakryptol yellow	15 gr.	1 g
Water (boiling)	16 oz.	500 cc
Ethyl alcohol, 95 per cent	16 oz.	500 cc

Dissolve the dye in the water and allow it to cool before adding the alcohol. Use at 65° F.

Plates should be immersed in the pinakryptol yellow desensitizer for 2 minutes in total darkness and then rinsed in water for exactly 30 seconds before commencing development, which may be performed under the direct rays of an Agfa safelight No. 103 with a 25-watt lamp.

After desensitization, plates may be developed by the factorial system by noting the time of the first appearance of the image (ignoring sky and brightest highlights).

FACTORIAL DEVELOPMENT TIME FOR AGFACOLOR ULTRA PLATES

<i>First appearance of image</i>	<i>Total developing time, including appearance</i>	<i>Correction for future exposures</i>
20 seconds	$2\frac{1}{4}$ minutes	Expose $\frac{1}{4}$ as long
25 seconds	$2\frac{3}{4}$ minutes	Expose $\frac{1}{2}$ as long
35 seconds	$3\frac{1}{2}$ minutes	Expose $\frac{1}{2}$ as long
45 seconds	5 minutes	Correct exposure
60 seconds	$5\frac{3}{4}$ minutes	Expose twice as long
2 minutes	8 minutes	Expose four times as long

After development, rinse the plate for about 1 minute in running water. Use a gentle spray, or water circulating in a large tray, but do not let the tap water fall directly on the plate, as the emulsion is too tender to stand that treatment. After rinsing, the plate is reversed in the following solution.

REVERSING SOLUTION

Water	32 oz.	1000 cc
Potassium bichromate	1½ oz.	50 g
Sulphuric acid, C.P.	3¼ oz.	100 cc

(Add the acid to the water while stirring slowly.)

For use, dilute with water 1 to 10. If the temperature of the working solution is allowed to go higher than 65° F., the emulsion is likely to leave the plate. The working solution may be used for several plates in succession, its exhaustion being indicated by becoming muddy and of a greenish tint.

After the plate has been in the reversing solution for a few seconds normal white light is turned on and the process continued until all the blackened silver on the plate has been completely removed, which may be judged by transmitted light. After this, the plate is washed in running water for 2 minutes and then returned to the original developer under strong artificial light or diffused daylight, where it is left until the emulsion becomes completely blackened, which will take 2 minutes or more.

As soon as the plate is thoroughly blackened, rinse for about 30 seconds in running water and then dry as quickly as possible in a gentle current of air. Do not apply heat to it, or too warm a current of air.

Agfacolor plates may be intensified with the usual mercury intensifiers, but preferably with the Agfa Mercury Intensifier which gives very close control over the amount of intensification. Intensification is a standard process for plates that are too thin on account of overexposure or overdevelopment, or both, and it gives considerable improvement in density and brilliance.

Reduction of underexposed or underdeveloped plates is not usually very successful, but it may be accomplished by using a 1 to 100 dilution of the stock reversing solution, or a much diluted Farmer's reducer.

After either intensification or reduction, plates should be washed for 1 minute in running water and then dried quickly as before mentioned.

When the plates are dry, they can be protected from injury by varnishing them in a solution of 3 parts gum dammar in 100 parts benzol. The varnish is flowed over the emulsion and any surplus allowed to drain back into the bottle from one corner of the plate.

When making separation negatives from Agfacolor Ultra plates it is advisable to use narrow cutting filters like the Wratten No. 29F red, No. 61N green, and No. 50L blue, with panchromatic, orthochromatic, and color-blind emulsions, respectively.

DUFAYCOLOR. — In this process, patented in 1908 and since greatly improved, the color is supplied by regularly ruled lines, which method has the advantage that the elements of such a pattern, or *réseau* as it is called, cannot clump together upon the film, as the grains of a mosaic screen are likely to do. The base of the film is printed blue, which is then overprinted successively by green and red lines which cross each other at an angle, and the blue is bleached out where these lines occur, resulting in alternate blue and green squares between red lines. These lines are ruled 23 to the millimeter, making about a million and a third color elements per square inch. Dufaycolor is made in several types which vary in color balance. One type has the filter compensation incorporated in the film and can be used in daylight without a filter, while other types cannot. They all require special filters for use with artificial light. The speed, in 1940, was Weston 8. Processing, which is similar to that of other additive processes, consists in a first development, bleaching, and redevelopment carried out as a continuous operation.

The Series 3 Wratten green safelight may be used when developing Dufaycolor if the film is not exposed directly to it. It is better to develop in total darkness for 3 minutes at 65° F. in the formula given below.

FIRST DEVELOPER

Metol	100 gr.	6.5 g
Sodium sulphite	1½ oz.	50 g
Hydroquinone	31 gr.	2 g
Sodium carbonate	1½ oz.	37 g
Potassium bromide	42 gr.	2.75 g
Potassium thiocyanate	144 gr.	9 g
Water	35 oz.	1000 cc

The above formula is for emulsions upon the American market, which are coated in America. For the emulsions on the English market, the following developer is recommended, 3 minutes at 65° F. being the normal time of development.

FIRST DEVELOPER (English)

Metol	130 gr.	6.5 g
Sodium sulphite	2 oz.	50 g
Hydroquinone	40 gr.	2 g
Potassium bromide	50 gr.	2.75 g
Ammonia, sp. gr. 880	210 minims	11 cc
Water to make	40 oz.	1000 cc

After development, wash for 1 minute in running water and then bleach in:

BLEACH

Water	35 oz.	1000 cc
Potassium permanganate	48 gr.	3 g
Sulphuric acid, sp. gr. 1.87	160 minims	10 cc

(Add the acid to the water with slow stirring.)

Agitate frequently and bleach until the image is clearly visible, which will require about 4 minutes. Rinse for 2 minutes and then clear for 2 minutes in:

CLEARING BATH

Sodium bisulphite (or Potassium metabisulphite)	400 gr.	25 g
Water	35 oz.	1000 cc

Wash for 3 minutes and then expose the film at a distance of about 1 foot for 1 or 2 minutes to a 100-watt lamp. Overexposure will do no harm.

The second development may be in the same developer that was used for the first development, or in any regular M. Q. developer. The following is suggested.

SECOND DEVELOPER

Metol	16 gr.	1 g
Hydroquinone	80 gr.	5 g
Sodium sulphite	1½ oz.	50 g
Sodium carbonate	309 gr.	20 g
Potassium bromide	16 gr.	1 g
Water	35 oz.	1000 cc

If the first developer is used for the second development, fixation is unnecessary because the developer contains a silver halide solvent, but if other developers are used it is necessary to remove the insensitive silver halide from the highlights. Any reduction in density of the positive in the process of fixation indicates that the second exposure to light or the second development was incomplete.

If the film is to be fixed, it should be rinsed well after the second development, and then fixed in any fresh, acid hypo bath. The following is recommended:

FIXING BATH

Solution A

Hypo	13 oz.	360 g
Potassium metabisulphite	185 gr.	12 g
Water	35 oz.	1000 cc

Solution B

Chrome alum	154 gr.	10 g
Water (cold)	35 oz.	1000 cc

Add solution B to solution A, fix for 3 minutes, and then wash for 15 minutes. This completes the process and the film is then ready to dry.

Over- or underexposure of Dufaycolor film may be compensated for by intensification or reduction. When intensifying, the film is first bleached and then redeveloped.

BLEACH

Ammonium chloride	360 gr.	24 g
Mercury bichloride	450 gr.	30 g
Water	35 oz.	1000 cc

Bleach completely, which will take about 4 minutes. Wash for 15 minutes and redevelop in one of the formulas below, according to the amount of intensification desired.

REDEVELOPER FOR SLIGHT INTENSIFICATION

Sodium sulphite	1 $\frac{3}{4}$ oz.	50 g
Water	35 oz.	1000 cc

REDEVELOPER FOR GREAT INTENSIFICATION

Ammonia	1 $\frac{3}{4}$ oz.	50 cc
Water	35 oz.	1000 cc

If the film has been underexposed or underdeveloped, resulting in too much density, it may be reduced in the following reducer.

REDUCER

Solution A

Hypo	1 $\frac{3}{4}$ oz.	50 g
Sodium carbonate	$\frac{1}{2}$ oz.	15 g
Water	35 oz.	1000 cc

Solution B

Potassium ferricyanide	80 gr.	5 g
Water	35 oz.	1000 cc

Mix equal parts of solutions A and B for use.

Great brilliancy may be obtained by slight reduction followed by intensification. Having washed the reduced film, intensify as above.

The speed of Dufaycolor is obtained by using dyes with a low degree of saturation and a wide spectral band of transmission. In making color separation negatives from Dufaycolor, this combination tends to dilute and degrade the colors where the transmission bands overlap. This necessitates the use of narrow-cutting filters when making reproductions, the "P" series for optical work, and the "S" series for contact work.

Duplicate transparencies can be obtained from the Dufaycolor Company, who have developed a special filter technique for this work.

FINLAY COLOR PROCESS. — The other additive processes which have been described are sometimes called combined processes because the color screen and the photographic emulsion are furnished in an inseparable unit. The Finlay process, which is a development of the principle used by Joly in 1894, and afterwards in the Paget plate process, makes use of an entirely separate color screen (*taking screen*) which is placed in contact with a panchromatic emulsion while the exposure is being made. After exposure the screen is removed and kept for future exposures, while the emulsion is developed as a regular negative. From this negative any number of positives can be printed upon special plates which, when bound in contact with separate *viewing screens*, display full color. Alternatively they may be printed upon special plates in which the screen is incorporated.

This process has several advantages over others. While a screen must be used over the lens when taking pictures, the speed is great enough for all ordinary photography. Any number of perfect duplicates may easily be made. Black-and-white prints or enlargements may be made from the original negative.

Best results are secured by the use of the special Finlay-Eastman plate which is made for this process, or by the use of Ilford Hypersensitive or Barnet Ultrasensitive panchromatic plates. A filter which compensates for the particular emulsion in use must be placed over the lens while taking the picture, and of such filters there are several varieties for different kinds of daylight and artificial light. The plateholder must be deep enough to accommodate both the panchromatic plate and the taking screen, which is ruled on glass and placed in contact with the emulsion of the photographic plate. The plateholder springs must be strong enough to keep plate and screen in close contact. In focusing, allowance must be made for the thickness of the taking screen, which displaces the emulsion from the focal plane.

In daylight the taking screen and compensating filter make a factor of about 6, by which the regular exposure for the panchromatic emulsion should be multiplied. An outdoor exposure in bright sunlight will average 1/25 second at $f:8$. Two medium-sized Photoflash bulbs at a distance of 5 feet will give a good exposure at $f:8$. Mazda light may be used, but Photoflood is unsatisfactory on account of the preponderance of blue when the bulb is new, and because the spectrum value of the light is constantly changing during the short life of the bulb. As a special filter has to be used for each type of light, one kind only should be used and all other kinds of light rigidly excluded.

Development should take place in absolute darkness by time and temperature unless the plates are desensitized and developed by inspection or the factorial method. Any soft-working developer can be used, and for this reason glycine is preferred by many workers, but the Finlay Company offers the choice of several, and the Eastman D-72 Elon-hydroquinone developer diluted 1 to 4, or D-76 in full strength, is often used. Be sure that the temperature of the developer never exceeds 65° F. because if the emulsion swells it will shrink irregularly when fixed and make registration with the viewing screen impossible.

METOL DEVELOPER FOR FINLAY PROCESS

Stock Solution A

Metol	$\frac{3}{4}$ oz.	35 g
Water (125° F.)	20 oz.	1000 cc
Sodium sulphite	$1\frac{1}{4}$ oz.	63 g

Stock Solution B

Sodium carbonate	$1\frac{3}{4}$ oz.	88 g
Potassium bromide	16 gr.	1.8 g
Water	20 oz.	1000 cc

Dissolve the ingredients in the order given. For normal use take equal parts of solutions A and B and dilute with an equal volume of water and develop for 3 minutes at 65° F. More or less of solution B may be used to meet special requirements.

GLYCIN DEVELOPER FOR FINLAY PROCESS

<i>Stock Solution</i>		
Water (125° F.)	48 oz.	1500 cc
Sodium sulphite	2½ oz.	75 g
Glycin	1 oz.	30 g
Sodium carbonate	4¼ oz.	129 g
Cold water to make	64 oz.	2000 cc

For use, take equal parts of the stock solution and of water and develop 5 or 6 minutes at 65° F. For subjects with a very long range of tones, the Finlay Company recommends that the negative be soaked for 3 minutes in a ½ per cent solution of sodium carbonate before development in the glycin developer.

The negative is fixed in any fresh acid hypo, or hypo-alum bath, and then washed and dried as usual.

Negatives may be slightly reduced with Farmer's reducer, or the regular persulphate reducer. Very contrasty negatives may be bleached and re-developed in the metol developer, stopping development when the proper degree of contrast has been reached by transferring the negative to an acid fixing bath.

BLEACH FOR REDEVELOPMENT OF FINLAY PROCESS

Potassium ferricyanide	1 oz.	10 g
Potassium bromide	1 oz.	10 g
Water	20 oz.	200 cc

Negatives may be slightly intensified by the chromium intensifier.

Either intensification or reduction is likely to cause trouble in this process, and should not be resorted to unless it is certain that contrast cannot be sufficiently modified when making the positive.

A slight amount of retouching may be done upon the negative, but any cross-hatching or other undue piling up of pigment will throw the positive out of register with the viewing screen, resulting in polychromatic streaks.

Only the Ilford, Barnet, or Eastman positive plates made for this process are suitable for the transparencies. They can be made only by contact printing, as any enlargement or reduction will change the size of the dots so that they will not register with the viewing screen.

Exposure is regularly made in a printing frame with springs strong enough to hold the negative in close contact over its entire area with the positive plate. As a basis for exposure, when using a Finlay-Ilford positive plate and

an average negative, an exposure of 20 seconds at 6 feet from a 15-watt light will be approximately correct.

The positive is developed in any of the developers recommended for the negative, keeping the contrast somewhat lower than would be acceptable for a monochrome lantern slide. Fix and wash thoroughly.

Before registering the viewing screen with the positive, brush the emulsion sides of both carefully with a camel's-hair brush to remove any dust, which would keep them out of contact. Place them together, emulsion to emulsion, with the viewing screen on top and register them by diffused transmitted light by sliding the viewing screen around with a circular motion until the crossed line pattern becomes larger and larger and finally disappears. Registration is then approximately correct and the screen and positive should be lightly held together by a clamp on each side while the screen is gently tapped for further slight adjustment. Look through the screen at various angles, and if the color appears to be better at a certain angle, move it slightly in that direction. When the colors are best, the circles of the registration band on the edge of the screen will be green. When registration is complete, bind with lantern slide binding the two edges that are not held by the clamps. Allow the binding to set a few minutes, and then, removing one clamp at a time, bind the other two edges. The color transparency will then be complete.

The Finlay Company makes a positive color screen which is a regular viewing screen coated with a positive emulsion, which may be used in place of separate plates and screens. If these are used, it is important that the color registering scales at the ends of the taking screen be properly recorded by exposure on the negative. This must be done before contact between the negative and the taking screen has been disturbed. The Finlay Company provides a special darkslide which has a long, narrow opening on each end, situated directly over the registering strips of the taking screen when it is in the plateholder. After the exposure for the picture, this darkslide is inserted in the plateholder and another exposure is made against the sky, a light wall, or a well-lighted sheet of paper, to record the color scales. This exposure must be about four times what would be a normal exposure.

The positive color screens should be opened only in a darkroom. A Series OA safelight with a 50-watt bulb will give light enough for registering them with the negative, which must be done before printing. Dust both screen and negative with a camel's-hair brush to free them from dust and insure perfect contact. The registering edge of the taking screen has a red outer band, a blue inner band, and green circles in between. When properly registered with the viewing screen, these marks show in their complementary colors, the circles being red, the outer band green, and the inner band yellow. Since we are dealing with a negative, all the colors of the picture will also be complementary at this stage.

When the two plates are registered, clip them on four sides with Acco clamps, No. 225, or spring paper clips. Examine with a magnifying glass to make sure that nothing but red is visible in the circles. If any other color appears, the final color rendering will not be good.

Place the clamped-together negative and color screen, negative up, on a piece of black cloth directly under an electric light for the exposure. A guide to average printing times will be found in a leaflet in the box in which the screens are sold.

Take off the clamps and develop the positive in Eastman D-72 diluted 1 to 4. Other developers may be used, but with care, as some of them are likely to change the colors. Amidol or glycine are often used for soft positives. Fix, wash, and dry as usual.

If a Finlay positive color screen is spoiled in development, it can be dried, then re-soaked in water for a few seconds, after which the photographic emulsion can be rolled off with the fingers, leaving the regular viewing screen on the glass, which can be bound up with a black-and-white positive.

Color separation positives are easily made from the original Finlay negative by the use of block-out screens provided by the Finlay Company. New negatives can be made from these, so that the Finlay process offers considerable advantage in separation work. By the use of block-out screens, sets of bromide prints can be made directly from the Finlay negative, thereby eliminating the step of making separation negatives for color prints.

OPTICAL DISPERSION PROCESSES are based upon the suggestion of Charles Cros in 1869 that by collimating the rays of light reflected by an object, separating them by a prism and using three lenses each of which would record one of the colored images, then making positives from the negatives so obtained and projecting them back through the same apparatus, a colored reproduction would be seen. This idea was worked out in various ways by many investigators, finally culminating in the lenticular process which was patented by R. Berthoin in 1909. Three apertures in the lens were covered with red, green, and blue filters and the exposure made through the support upon which were embossed microscopic lenses which focused three separate colored images on the emulsion. The negative was reversed into a positive and projected through apparatus similar to that used in making the exposure. A method of preparing the lenticular support upon celluloid perfected by A. Keller-Dorian in 1914, made the process practicable, and it was the basis of *Kodachrome*, an additive motion picture process put on the market by Eastman Kodak Co. in 1929.

THE LIPPMANN PROCESS. — Interference heliochrome has been used for color reproduction since the early experiments of Niépce in 1829 which played their part in the invention of the daguerreotype, but without much practical success. The most interesting and perhaps most significant results were obtained by Lippmann in 1897 by backing a plate with a metallic

mirror formed by a layer of mercury. After exposure, the mercury was removed, the plate developed, fixed, washed, and dried in the ordinary manner. While the plate was wet no color was visible but it appeared gradually as the plate dried. For viewing, the plate had to be mounted against a black background, such as black velvet, and illuminated by light falling directly on it. If viewed at an angle, the colors are modified. If viewed by transmitted light, it appears as a black-and-white negative, but by reflected light it is a colored positive.

For its perfection, this process requires a perfectly transparent and grainless film through which light would pass without scatter. Light striking the emulsion is reflected back along its original pathway by a metallic mirror in intimate contact with the emulsion, and so "interferes" with light coming in the opposite direction. Waves in opposite phase meeting each other cancel out and have no photographic effect, but at points midway between, the effect is cumulative, giving double the intensity of image. The image consists of dark layers in the emulsion which are separated by one-half the wavelength of the light that produced them. Light incident upon this image is largely absorbed, but rays of the same wavelength that produced the interference layers are reflected in their natural colors.

. The Lippmann process gives colors of great accuracy, but it has never been used commercially because no film sufficiently grainless and translucent to give satisfactory results is available, and also because of the difficulty of viewing the plates.

SUBTRACTIVE COLOR PROCESSES are suitable for making either transparencies or prints, whereas the additive processes are satisfactory only for transparencies because their colors are too weak to be viewed by reflected light. But the convenience of the additive processes, just described, for making transparencies was never rivalled by any subtractive process until Kodachrome and the New Agfacolor appeared upon the market.

KODACHROME as originally introduced by Eastman Kodak Company in 1915, was a two-color subtractive process using a double-coated film. The positives were bleached with a tanning bleach and dyed with dyes that penetrated the soft gelatin preferentially. The later process which was introduced in 1936, first for 16 mm motion pictures and afterwards for use in still cameras, consists of a multilayer monopak containing three emulsions which are superimposed upon the same base. These emulsions are sensitive respectively to the three primary colors and are insulated from each other by layers of dyed gelatin which act as filters, yet the whole pack of five layers is only 0.001 inch thick. The outer emulsion is sensitive only to blue and forms the blue image, any residual blue light being absorbed by a layer of yellow gelatin beneath it. The next emulsion, to which only red and green rays can penetrate, is sensitive only to green, and forms the green image. A layer of red gelatin

beneath this allows only red rays to penetrate to the final emulsion which is sensitive to red rays from 600 $m\mu$ to 700 $m\mu$.

Processing is quite complicated and can be done only by the company's own machinery especially designed for the purpose. In one continuous operation the three layers are developed to produce three different positive dye images which are complementary in color to the color to which the different emulsions were originally sensitive. The whole film is first developed as a negative and then reversed into a positive, the positive image being developed with a dye-coupling developer which forms in the film at the same point as the reduced silver, a deposit of blue-green dye. This dye is bleached out, in the two upper layers only, by the controlled diffusion of an alcoholic bleach and these layers are then redeveloped in a magenta dye. The top layer is again bleached, and redeveloped with a yellow dye. The silver images are then bleached away, leaving only the superimposed yellow, magenta, and blue-green images in dyes which are practically grainless and very transparent, making them ideal for projection without the excessive amount of light needed to project transparencies made by additive processes. Kodachrome is fast enough for all ordinary instantaneous exposures. It is made in two types, one for daylight and one for artificial light, and is normally used without a compensating filter on the lens, but either type of film can be used with any kind of light with a suitable filter. Negatives for making black-and-white prints from Kodachrome are easily made by printing the Kodachrome upon a panchromatic film such as Panatomic.

NEW AGFACOLOR is similar to Kodachrome except that the color formers are placed directly in the different emulsions and are reduced *in situ* with the silver by the use of a dye-coupling developer during the second (positive) development, after which the silver is removed, leaving only the dye images. New Agfacolor can be easily processed by the individual worker in an ordinary darkroom.

GASPARCOLOR, introduced about 1932, was the first to utilize a single film with three layers of dyes sensitized to the primary colors. Up to the present writing, it has been used only for printing colored positives from three-color separation motion-picture negatives made in special cameras.

THREE-COLOR SEPARATION NEGATIVES. — For making prints in color, and for other purposes, it is necessary to make color separation negatives which must be identical in the size and sharpness of the image and vary only as their densities record different colors. They must be made through three filters that divide the spectrum into three approximately equal parts, overlapping only enough to ensure complete coverage. A scale of gray tones must be rendered the same on all three negatives so as to obtain color-free rendering of grays and whites and the proper balance of the colors.

In an ideal set of filters the blue would cover from 400 to 500 $m\mu$, the green from 480 to 600 $m\mu$, and the red from 580 to 700 $m\mu$. In this way the

blue-green occurring between 480 and 500 $m\mu$ would be covered by both the blue and the green filters, and the yellow occurring between 580 and 600 $m\mu$ would be covered by both the green and the red filters and so these transitional bands (see page 287) would be properly rendered. While no available dyes permit the making of filters which exactly duplicate these ideals, the Wratten filters A, B, and C-5, the Agfa 40, 41, and 42, and the Ilford tricolor red, green, and blue closely approximate them and are the ones most commonly used. While these sets of filters are very similar, it is advisable to use the set recommended by the manufacturer of the sensitive material that is being used.

Either glass plates or film are used for the separation negatives. Plates are free from uneven expansion and contraction in processing which would throw the images out of register, but little trouble is experienced with films if they are all on the same type of base and receive uniform processing. All three negatives may be made upon panchromatic material, using suitable filters for each negative, but color separation is also obtained by using a color-blind emulsion with no filter for the blue-sensation negative; an orthochromatic emulsion with a yellow filter for the green-sensation negative; and a panchromatic emulsion with the tricolor red filter for the red-sensation negative. Sometimes the color-blind emulsion without filter is used for the blue-sensation negative and panchromatic emulsions with suitable filters for the other two negatives. The use of panchromatic emulsion for all three negatives is perhaps the most desirable procedure as it avoids all trouble from different emulsion characteristics, but the other methods are much used because they result in higher speeds or because the separation methods used demand them.

Lenses. — A reliable anastigmat lens must be used for making color separation negatives. Cheaper lenses often do not focus the image through the three filters in the same plane, resulting in unsharpness in one of the images, or in lack of registration. This defect can be largely remedied by stopping down, but this occasions a prohibitive loss of speed. The lens should be as fully corrected for color as possible, but any well-corrected anastigmat gives acceptable results. An apochromat is ideal when it can be used (see page 7). An adequate lens hood to minimize flare should always be used.

METHODS OF COLOR SEPARATION. — Color separation may be made with an ordinary camera, changing the plate and filter for each exposure and varying the time of exposure in accordance with the multiplying factor for each filter. This method cannot be used upon any subject in which movement may occur, or upon which the lighting may change, during the time necessary to make the exposures. The camera must be very rigidly supported, and the extension between the lens and groundglass securely locked so that it will not be disturbed when changing the sensitive material.

Repeating backs, which may be adapted to many cameras, are a great convenience if much separation work is to be done. The holder of the repeating

back is loaded with all three negatives at once, with the appropriate filters in place in front of each, and they are exposed in succession by either manual or automatic operation, resulting in all three exposures being made inside of 3 or 4 seconds.

Tripacs may be used in an ordinary camera. They consist of three films, each sensitive to one of the primary colors, the back of each of the first two films being coated with a dye which prevents the passage of any color not wanted on the remaining emulsions. As the three films lie in different planes, however close, and as there is a scatter of light by its passage through the different films, this process is limited to work which does not require critical sharpness. It also necessitates a long exposure with small latitude, and it is difficult to secure equal densities in all three negatives with the same exposure.

Tricolor cameras are so constructed that the light which enters through the lens is split into three parts, each part striking a different emulsion behind an appropriate filter, resulting in three separation negatives at one shot, hence these cameras are popularly called *one-shot* cameras. The direction of the light is controlled by two mirrors, called *beam-splitters*, which reflect part of the light and transmit part. Glass has several disadvantages and these mirrors usually consist of a thin membrane of collodion on an optically flat frame, forming what is termed a *pellicle mirror*. They are easily damaged and unless carefully mounted are affected by climatic changes. Exposures in this type of camera must be comparatively long because only a small fraction of the light is available for making each negative. The light is divided into three parts of which only one part is used for making each negative. Further loss is occasioned by the filters, and by the amount of light absorbed by the mirrors, as the sum of the light reflected and transmitted by the beam-splitters can never be equal to the total amount of light incident upon them. The total loss approximates 90 per cent of the light admitted by the lens.

Bi-pack-plus-one cameras are faster than the tricolor because they have only one beam splitter, which deflects part of the light to a blue-sensitive film, while the remainder is transmitted through a yellow filter to a bi-pack consisting of an orthochromatic film face to face with a panchromatic film, the two emulsions being separated by a very thin layer of red gelatin which acts as a filter for the rear film.

Single-shot cameras are quite costly, but very convenient as, notwithstanding the loss of light inherent in their principle, they are the only means of making separation negatives with instantaneous exposures. They are speeded up by using a color-blind emulsion for the blue and an orthochromatic for the green, instead of panchromatic emulsions for all three, thus reducing the filter factors. While a camera with a single beam-splitter costs less than one with two, it has the disadvantage that there is inevitably some diffusion in the rear negative of the bi-pack occasioned by diffraction of the light while passing first through the other film. This type is therefore not capable of quite such

critical definition as the type with two mirrors, but it has the advantage of being able to allow much faster exposures because the light is split only once instead of twice.

Reference Charts. — The three separation negatives must balance in density and contrast in order to record colors correctly. The easiest and only sure way to secure this balance is by including a scale of gray tones in the picture. While it is advantageous to use a longer scale when making negatives for photomechanical purposes, for negatives for ordinary positive printing by the usual processes three adjoining squares of black, medium gray, and white paper are sufficient. Such squares are easily made by suitable exposure on bromide paper. They can be mounted upon a card and placed or suspended so that they will appear in a part of the negatives that can be trimmed off on the final print, taking care however that they are so placed that they will receive approximately the same lighting as the principal object in the picture. It is also convenient to place upon the chart, alongside these squares, narrow rectangles colored respectively yellow, magenta, and blue-green with the initial of each color painted in black upon it. When the negatives are developed, the yellow printer will then show a sharply defined Y on a clear ground while the other two strips will be black. Each of the other negatives will likewise display its own initial and obscure the others, thus making the identification of the negatives certain and easy.

Exposure. — No specific directions can be given for exposure times because they vary so greatly with the kind of light used, the type of emulsion employed, and the multiplying factors for the different filters. The basic exposure time can be ascertained by the use of a photo-cell exposure meter, and this multiplied by the factor for the filters for the light that is being used. The filter factor for each batch of emulsion is usually stated by the manufacturer on a slip included in the box with the film, and this factor should always be used instead of any general factor for that type of emulsion, as exposures must be exact within very narrow limits.

Development. — All three negatives in a color separation set must be developed to the same gamma so that their contrasts will be the same. If they are all upon the same emulsion, standardized time and temperature development will secure this upon some special emulsions, but upon most emulsions the negative exposed under the blue filter will require from 25 per cent to 100 per cent longer development, under otherwise identical conditions, to bring it up to the gamma of the other two negatives. This time can be learned only by trial. When using different emulsions in the same set of negatives, it is essential that they all have a similar shape of reproduction curve. Most manufacturers will furnish graphs or instructions by which their emulsions can be developed to any given gamma. Failing other methods of getting identical contrast, one or more of the negatives may be intensified, but reduction is not recommended.

The actual amount of contrast desirable in a set of separation negatives depends upon the nature of the printing process for which they are to be used and whether they are to be printed by contact or enlargement, and if by the latter means, whether a condenser or a diffused-illuminant enlarger is to be employed. The sponsors of any printing process will recommend a suitable gamma for it.

Gamma is the most important consideration in development. It is also desirable to have identical density in the different negatives and if the exposure under the different filters has been properly correlated, this will be secured automatically by standardized development, but if slight density differences occur they can be largely compensated for in printing.

It is very difficult to compare visually the density and contrast of the subject matter of the negatives because the content of the different colors varies so greatly, but the gray wedges should be identical on all the negatives, and these are easily compared either visually, or more accurately by a densitometer. There are several quite inexpensive densitometers on the market that give satisfactory results.

The negatives should be developed in the formula recommended by the manufacturer, either in tank or tray. The processing should be very carefully done to insure even development, free from all streaks and stains, and the temperature should be kept at 65° F. for best and most uniform results.

If cut films are used, the whole set should be washed for the same length of time, and each film should be dried by being suspended from one corner, which must be the same corner on each negative. With these precautions, a set of cut film negatives can be processed with no more change in size between them than 0.0001 inch, which is negligible.

COLOR PRINTS are made from color separation negatives by producing from each a positive transparency in a color complementary to the original taking filter, and superimposing these transparencies in register. Several hundred different methods have been proposed for making color prints, but only a few have met the test of practical use. In these practical processes the colored images are obtained either by pigment transfer as in carbro, by toning and dye-mordanting as in Chromatome, or by relief images and imbibition as in Wash-Off Relief, or by some combination of these methods.

TRICHROME CARBRO. — For many years the most practical method of getting a color print was by the carbon process, but this has given way to carbro, in which the size of the finished print is in no way limited by the size of the separation negatives. The process in general is the same as that for regular carbro (page 239) except that special trichrome tissues which are coated with the three primary colors are employed. These are sensitized, placed in contact with bromide enlargements from the corresponding negatives, and then removed to sheets of celluloid upon which they are developed. They are after-

wards stripped from the celluloid and superimposed in register upon a "soluble temporary support," from which they are transferred to the final support.

The paper for the bromides is best cut from rolls, to make sure that the grain runs the same way in each sheet of a set so that they will all stretch the same way when wet, and retain their register. Prints should be so exposed and developed that the scale of grays is identical on all three prints. There should be a slight tint over the white section of the scale. Eastman D-72 is much used by color workers for developing the bromide print, but some prefer amidol, which should be made up at the time of use as it does not keep for more than a few hours in solution.

AMIDOL DEVELOPER

Water	20 oz.	590 cc
Sodium sulphite	1½ oz.	42.5 g
Potassium bromide	10 gr.	0.7 g
Amidol	40 gr.	2.6 g

If trouble is encountered in getting uniformity in the gray scale on prints from the different negatives, contrast may be modified by using the Eastman D-64 developer, suitably diluted.

Use a fixing bath containing only hypo and potassium metabisulphite. Do not use alum.

Prints may be hung up to dry, or swabbed off and placed upon lintless cloth stretchers. Drying between blotters is likely to cause trouble with the unhardened emulsion.

The red, blue, and yellow carbon tissue is cut about an inch larger all around than the prints, sensitized according to the regular carbro practice, and squeegeed to the prints, taking care to get each color on the correct print, which can be determined by the reference chart which is printed on it. The time that the print and the pigment are left in contact is not critical, but it must be long enough to enable the print to set up the maximum insolubility in the bichromated pigment. Sometimes 5 minutes will do this, but 15 minutes is safer, and does no harm.

At the expiration of this time, the tissue is stripped from the bromide print, immersed for 1 minute in a solution of equal parts of alcohol and water, and then squeegeed firmly on to a sheet of celluloid an inch or more larger all around than the print. This celluloid must have been previously waxed in a special waxing solution furnished by the Autotype Company, which also furnishes the color tissue, the celluloids, and all other materials necessary for this process. George Murphy, Inc., 57 East Ninth St., New York City, are the American agents. The waxing must be done with great care, distributing a small amount of wax over the entire surface and then polishing it vigorously with a dry cloth until little more than the polish remains. If properly polished it is sometimes difficult to determine at a glance which side of the celluloid contains the wax, and for quick identification it is well to clip one corner of the sheet so that

when it is held with the clipped corner in a certain position, say in the upper right-hand corner, the waxed side will be facing you.

If frilling occurs during the development of the tissue on the waxed celluloids, they will have to be given a coating of hardened albumen. Beat the white of an egg to a froth and add 15 ounces (450 cc) of water. Dissolve 150 grains (9.7 g) potassium bichromate in 5 ounces (150 cc) of warm water and add to the egg and water. Stir well, and filter twice through cheesecloth. One-half ounce (15 g) of powdered egg albumen may be used instead of the white of egg. This solution will keep for some time if stored in a dark bottle, and may be used repeatedly until its odor becomes too offensive. The waxed celluloids are immersed in this solution in which they are rocked for about a minute, then drained for a few moments and then rinsed by shaking for about 15 seconds in a tray of cold water, after which they are hung to dry in daylight or strong artificial light, which makes the albumen insoluble and gives a frill-proof coating upon which to develop the pigment images.

The pigment papers which have been taken from contact with the bromide prints are squeegeed on to the celluloid and left under slight pressure for about 15 minutes. The celluloids with the adhering pigment are then immersed and developed in water at 105° F. To prevent frilling, a weak solution of chrome alum may be added to the water.

STOCK SOLUTION

Chrome alum	300 gr.	30 g
Water to make	10 oz.	400 cc

Add $\frac{1}{4}$ ounce of this stock solution to each 16 ounces (12 cc to 1000 cc) of the water at 105° F. used for developing.

Develop until no color will run from them, rinse in a tray of fresh, warm water, chill in a tray of cold water, and hang up to dry. As soon as the pigment has begun to set, drying may be hastened by the use of a fan.

The next step is to transfer the three pigment images from the celluloids into register on a *temporary soluble support*. A special paper is furnished by the Autotype Company for this purpose. Cut the paper from the roll to a size a little larger than the print. Soak it for 5 minutes in water at 70° F. If the water is too cold the gelatin will not soak up sufficiently to pick the entire image off from the celluloid. At the end of 5 minutes transfer the temporary soluble support paper, face down, to a deep tray of water at about 60° F. Slide the celluloid with the blue image into the water under the temporary soluble support and bring them into contact and draw them out of the water together carefully so as to avoid air bells. Slide the paper around so that there will be a margin of white all around the print. Place the celluloid and the paper together on a squeegee board and squeegee them into contact. A blotter can be placed over them and a roller squeegee used. Remove the blotter and dry off all surplus moisture with a cloth and place the celluloid

with the adhering paper in a gentle current of air to dry. When dry, the soluble paper can be stripped from the celluloid, taking with it the entire blue image. The celluloid is then placed to one side to be washed with mild soap and water and afterwards rewaxed for further use.

A film of wax from the celluloid will be left over the pigment image and this must be thoroughly cleaned off with a piece of cheesecloth soaked in pure refined spirits of turpentine. Let the turpentine set a few minutes to soften the wax, then with a fresh cloth soaked in benzene or naphtha, go over the print again to remove the turpentine and wax. Polish with a dry cloth. The benzene and dry cloth treatment may have to be repeated a couple of times to remove all of the wax. When the wax is entirely removed, place the paper with the blue image in cold water for about 2 minutes, until it is fully expanded.

Place the celluloid with the red image face up in a tray of cold water for about one-half minute. Place the fully expanded blue image over the red image on the celluloid under water, being careful to avoid any air bells. Hold the celluloid and the paper together at one end and draw slowly out of the water. When entirely out, lift the celluloid slightly from the paper and looking through the celluloid side, bring the images into approximate register. Lay them flat with the paper side up on a squeegee board and with a flat squeegee give them a light stroke to remove the surplus moisture between them. Place them inside a folded blotter and go over them lightly with a roller squeegee, then remove from the blotter and carefully wipe off all drops of water from the paper and from the back of the celluloid. Then turn them over so that the celluloid side is on top and slide the blue image about until it coincides with the red. Register the center first and work out towards the corner. This should be done in a cold room and the fingers should occasionally be dipped into cold water so that heat from them will not injure the print. When registration is perfect, wipe the celluloid side with a dry cloth and look carefully for air bells which must be wiped off. Remove all surplus moisture from both the celluloid and the paper carefully, and set them up to dry as before. When dry, the paper can be stripped off, taking with it the combined blue and red images.

The combined prints on the paper must be cleaned with turpentine and naphtha the same as before, and the yellow image then added in the same way that the red was put on.

The three-color print is now held upside down by the temporary support and it is only necessary to transfer the combined images to the final support, which consists of a piece of *single transfer paper* larger than the temporary soluble support. This is first soaked for 15 or 20 minutes in warm water and then chilled in cold water. The combined image is placed in cold water to soak until it is limp, which will take about 5 minutes, after which it is placed face down on the gelatin side of the single transfer paper under cold water. Take

the two out of the water together, being careful to avoid air bells, and squeegee the combined images and the final support paper into contact. Place them between blotters and roll them with a print roller, then place them between dry blotters under a moderate weight, such as a sheet of glass, for about 20 minutes, then hang in the air until relief begins to show around the print, which will take about 10 minutes. Then slide the entire combination with the temporary soluble support underneath, into a tray of water at about 105° F. After a few minutes the paper backing of the temporary soluble support will begin to peel off from the combined colored images, leaving them on the final support. As soon as the papers begin to separate, the action can be hastened by gently pulling them apart. If they do not loosen up in a few minutes, the temperature of the water must be raised. The completed color print is now right side up on the final support. Bathe it gently with warm water to remove any surplus gelatin, then chill in cold water and hang the print up to dry.

Carbro is best worked at a uniform temperature of 65° F. with a humidity between 50 and 60. While occasional work can be done under makeshift conditions, it is almost imperative, if a considerable volume of work is to be attempted and uniform results secured, that controlled temperature and humidity be available in the workroom.

BELCOLOR is a very simple and convenient method for obtaining transparencies in color from separation negatives. This process also offers considerable advantages in making three-color gravure positives, and a variation of it furnishes prints upon paper. The materials are supplied in America by George Murphy, Inc., 57 East 9th Street, New York City. These consist primarily of thin sheets of celluloid coated with an unsensitized layer of colored gelatin in the complementary colors red, blue, and yellow. Other colors are also available for special purposes. One sheet of each color is sensitized, and then printed through the back from the corresponding separation plate. The resulting positives are developed by simply washing in water and are then superimposed in register to form the color transparency. Sensitize in a cool but not a cold room. If the sensitizer is cold, the potassium bichromate will be precipitated and cause grain.

REGULAR BELCOLOR SENSITIZING FORMULA

Water	35 oz.	1000 cc
Potassium bichromate	1½ oz.	40 g
Ammonia	3 drams	10 cc

This regular formula should be used whenever possible. In hot and moist conditions, it is sometimes advisable to use a quick drying formula.

QUICK DRYING FORMULA

Water	25 oz.	700 cc
Potassium bichromate	1 oz.	28 g
Columbian Spirits	25 oz.	700 cc

This quick drying formula does not give so fine a grain as the regular formula.

The celluloids should be sensitized in either one of the above formulas for 3 minutes at 60° F. Remove them from the sensitizer and place them upon a sheet of cool glass. Pass a squeegee lightly over the celluloids to squeeze out as much moisture as possible, then swab them with moist cotton to remove all the surplus moisture, and hang to dry. Drying will take an hour for the regular formula and about one-half that time for the quick drying formula. Dry in a dark room as the emulsion becomes sensitive as it dries.

Printing is done through the back and it is essential that the back of the celluloid be thoroughly cleaned with absorbent cotton before printing. Printing should preferably take place between 4 and 24 hours after the celluloids have been sensitized. The longer the time elapsing between the sensitizing and printing, the more difficult will the developing be, but this can be quite largely compensated for by raising the temperature of the water in developing.

If the separation negatives have been balanced, the printing time will be the same for all the negatives. Cooper-Hewitt tubes or arc lamps are the most reliable printing lights, but Photoflood or a sufficient bank of Mazda bulbs can be used. The printing time can be ascertained by printing one of the negatives upon printing-out paper until the white of the gray wedge on the reference chart is barely tinted. Attach a metal or wooden clip to the celluloid by which it can be handled, so that the contact of warm fingers will not soften the emulsion. Develop in water at 105° F., keeping the celluloid constantly agitated by rocking the tray and shaking the sheets by means of the clip. As soon as the image appears to be cleared, rinse the sheet in lukewarm water, chill 1 minute in cold water (not more than 65° F.), and examine the sheet by transmitted light to see if the white part of the gray wedge is clear. If it is not, the sheet should be returned to the hot water for further development.

When each color has been developed and transferred to cold water, the sheets are taken out one at a time and superimposed in register upon a sheet of flashed opal or groundglass with a suitable light beneath it. If the colors are not correctly balanced, one or more of them is returned to the developing water for further reduction. For this purpose the water can now be raised to a temperature as high as 125° F., or the action can be accelerated by the addition of 1 ounce of a 5 per cent solution of sodium carbonate to each 65 ounces of hot water.

When the color balance is correct, the sheets are individually washed under running water to remove all surplus color. The backs can be rubbed with wet absorbent cotton to remove any color that they may have picked up during the registering.

When the sheets are thoroughly washed they are hung up on a line to dry and this process may be speeded by the use of a fan. Any wet spots upon

the back of the sheet should be carefully removed with a swab of dry absorbent cotton.

After the color films are dry, they are bound in register between a sheet of plain glass and one of opal, and the transparency is complete.

Color Gravure Positives. — The Belcolor Company furnishes transformable natural color film celluloids for this process, by which colored positives, after they have been examined and checked for registration and color balance, are transformed into the equivalent of black-and-white positives which retain the same proportionate tone as the color positives. This is a very convenient method of getting positives for printing on carbon tissue resists for color printing.

The sensitizing, drying, printing, and developing of the transformable film is identical to the regular Belcolor process. When the films are dry they are again soaked in cold water for about 5 minutes, after which they are placed from 3 to 5 minutes in the following developer.

BELCOLOR TRANSFORMING DEVELOPER FORMULA

Water	34 oz.	1000 cc
Metol	77 gr.	5 g
Hydroquinone	155 gr.	10 g
Sodium sulphite	1½ oz.	50 g

For normal results add to the above 34 ounces (1000 cc) of a 20 per cent solution of potassium carbonate. For contrasty results add 32 ounces (900 cc) of a 1 per cent solution of caustic soda.

After development, wash 5 or 10 minutes in cold water to remove the developing solution and after drying, the gravure positives will be complete. This process has the advantages that control can be exercised in the original washing out of the color sheets in the hot water and that the final color results can be seen in the positives before converting them into black and white.

Color Prints by Belcolor. — The Belcolor Company furnishes a coating solution which may be used for regular Belcolor transparencies, or by stripping, for obtaining prints in color upon paper. The sensitizer is mixed according to directions which accompany the solution. A clean sheet of celluloid about 0.01 inch thick is laid face up upon a whirler and the sides taped down with Scotch tape to insure the sheets lying flat. The whirler is started, and a small portion of the prepared Belcolor solution is poured into the center of the sheet and allowed to spread out evenly towards the edges. The whirler is kept in motion under a current of cool air until the sensitizer dries. This procedure must be done in a dark room. When dry, the film is printed as in the regular Belcolor process.

After exposure, each sheet is washed in *cold* water until all the insoluble color is washed away, giving three separation images on celluloid sheets. These can be superimposed in register over a light and the registration and

color balance checked to make sure that they are correct, after which they are hung up to dry. These celluloids can be bound up in register between glass as regular colored transparencies, or transferred to paper as a color print.

Paper such as the Autotype Temporary Soluble Support is soaked in cold water and squeegeed into contact with the yellow image which has been placed in cold water for 1 or 2 minutes. Care should be taken that the temporary soluble support is always soaked for the same length of time in a given temperature of water, about 65° F. After drying slightly by hanging in the air, the sandwich is put between two blotters under heavy pressure and left until dry. When dry, it will be found that the yellow image is attached to the paper, having become detached from the celluloid, which is then available for use in making another print. The yellow image on the paper is now soaked in cold water for 1 or 2 minutes and registered against the red image on its celluloid, squeegeed and dried in the same manner as before. This operation is repeated for the blue image.

When the print is complete upon paper, it should be soaked for 5 or 10 minutes in a 5 per cent solution of chrome alum to harden the gelatin of the temporary soluble support. After drying, the colored print is complete.

CHROMATONE, introduced by the Defender Photo Supply Company, Inc., in 1935, utilizes collodion stripping paper on which prints are made and then toned in tricolor toners, stripped from the original bases, and then assembled in register on a new paper support.

From three separation negatives a set of prints is made, preferably by projection, upon Chromatone print paper which is supplied either in regular or soft grades. In the final assembly, these prints may be placed either with the emulsion or the collodion side up depending upon the effect desired and after-processes contemplated. This must be decided in advance because if the prints are to be assembled with the emulsion side up, they are printed with the negatives in the regular position; but if they are to be assembled with the collodion side up, the negatives must be reversed at the time of printing.

The toning operations slightly alter the regular strength of the black-and-white positive so that they cannot all be printed to the same density. By test exposures, determine the time necessary to produce identical gray scales on the three black-and-white prints, then expose the print to be toned yellow 25 per cent longer than the time needed to match the gray scale of the correctly printed magenta print. Expose the print to be toned blue-green 15 per cent longer than the time required to match the gray scale of the magenta print. The result will be a normal print for the magenta, an overexposed print for the yellow, and a very fully exposed print for the blue. The prints should be made with a white margin of $\frac{1}{4}$ to $\frac{1}{2}$ inch all the way around and each print should be marked on the bottom with waterproof India ink indicating the color to which it is to be toned. Thus the print from the negative made through the blue filter should be marked "Y" because it is to be toned yellow.

The other prints should be similarly marked "M" and "B-G." If the water-proof India ink is allowed to dry thoroughly, which will take only a few seconds, it will be impervious to the further operations.

The three prints should be developed together in the same solution so that they will all have identical treatment. The emulsion is very fast and should be handled only under the regular series OA safelight. Control of the contrast of the print can be exercised by using different developers.

NORMAL CHROMATONE DEVELOPER

Water	40 oz.	2000 cc
Metol	15 gr.	1.5 g
Sodium sulphite	$\frac{1}{2}$ oz.	22.5 g
Hydroquinone	60 gr.	6.5 g
Sodium carbonate	$\frac{1}{2}$ oz.	22.5 g
Potassium bromide	25 gr.	2.7 g

Develop for $1\frac{1}{2}$ minutes at 70° F.

SOFT CHROMATONE DEVELOPER

Stock Solution

Water	32 oz.	1000 cc
Metol	44 gr.	3 g
Sodium sulphite	1 oz., 88 gr.	36 g
Sodium carbonate	263 gr.	18 g
Potassium bromide	58 gr.	4 g

Working solution, 1 part of stock solution to 3 parts of water. Develop 3 or 4 minutes at 70° F.

VIGOROUS CHROMATONE DEVELOPER

Stock Solution A

Water	32 oz.	1000 cc
Hydroquinone	$1\frac{1}{2}$ oz.	45 g
Sodium sulphite	1 oz.	30 g
Sulphuric acid	60 minims	4 cc

Stock Solution B

Water	32 oz.	1000 cc
Sodium carbonate	4 oz.	120 g
Potassium bromide	120 gr.	8 g
Sodium sulphite	3 oz.	90 g

Use equal parts of solutions A and B and develop 5 minutes at 70° F.

It is advisable to use a regular acetic acid short-stop between development and fixation. Fix in a regular acid hypo bath or in the following:

THIOCYANATE FIXING BATH

Potassium thiocyanate	$3\frac{1}{2}$ oz.	100 g
Potassium alum	$1\frac{3}{4}$ oz.	50 g
Water	32 oz.	1000 cc
Glacial acetic acid	1 oz.	25 cc

This fixing bath is very convenient when speed is necessary as the washing need not be very thorough, since traces of this solution will not interfere with toning operations. In the fixing bath the films can be stripped from the backing paper, which is thrown away. Wash the black-and-white Chromatone prints not less than 15 minutes in rapidly running water or in five or six complete changes of water in a tray.

Toning. — The second step in making Chromatone prints is toning, which can be carried out in white light. Toning consists of two operations, the first of which is really a bleach and the second supplies the color to the film. These toning solutions are furnished by the Defender Photo Supply Company and are labeled A and B in the order of their use. Toning should be performed in clean glass or perfect enamel trays. Any metal that comes in contact with the toning solutions will contaminate them. Thermometers should be all glass. The temperature of toning solutions should not exceed 70° F. as with higher temperatures loss of highlights may occur. A swab of absorbent cotton or a wide rubberset brush is very useful for keeping the toning solutions continuously applied to the emulsions. These brushes or swabs must not be transferred from one solution to another. Before toning, swab the back of the prints to remove any adhering coating where the paper was stripped off, as this may contaminate the toner.

The black-and-white positive prints for the *red and blue* images are placed together in one tray and the red and blue working solution of Red Toner A is added.

RED AND BLUE TONER A (Working Solution)

Water	1 oz.	25 cc
Red and blue toner A	1 oz.	25 cc
Standard ferricyanide solution	1½ drams	5 cc

This working solution does not keep well when mixed and only enough should be prepared for prints in process.

STANDARD FERRICYANIDE SOLUTION

Potassium ferricyanide	½ oz.	11 g
Distilled water	4 oz.	100 cc

The red and blue prints should be kept in the A solution for at least 15 minutes, until all of the black silver is removed, leaving the prints a light greenish-brown tone. They are then placed in running water and thoroughly washed for about 10 minutes, or in five complete changes of water in the tray.

It is very essential that the hands be kept scrupulously clean at all times in order not to contaminate one solution by transferring any traces of another to it.

After this washing, the *red* image is placed in the Red Toner B and allowed to tone for about 10 minutes. The toning proceeds to completion and a little

longer time in this bath will do no harm. Toner B is used without dilution or additions, as furnished by the manufacturer.

After toning, the solution is poured off and saved for future use, and the print is fixed for 3 minutes in:

STANDARD HYPO SOLUTION

Granular or rice hypo	2½ oz.	70 g
Distilled water	32 oz.	1000 cc

This formula must be used wherever Standard Hypo Solution is called for. A fixing bath containing acid or alum would cause complete failure of the process. After the second toning and fixing in the Standard Hypo Solution, the red print is washed for about 15 minutes in running water, or in five or six complete changes of water, and is then ready for assembling.

The *blue* image, after treatment in solution A and the ensuing wash, is placed in the Blue Toner B for about 10 minutes, after which the toner is poured off for use a second time and the print immersed for 1 minute in a weak solution of hydrochloric acid.

DILUTE HYDROCHLORIC ACID

Hydrochloric acid, C.P.	16 oz.	500 cc
Distilled water	48 oz.	1500 cc

For use, take 1 part of the dilute solution with 2 parts of water. The print is then thoroughly washed in running water for about 10 minutes, or in five complete changes of water, after which it is placed in a tray of Standard Hypo Solution until its greenish tones have changed to blue. It is then washed for about 20 minutes, or in six complete changes of water, after which it is ready for assembling.

The *yellow* image must be toned individually in its own first toning bath. It is first treated for about 10 minutes in the Yellow Toner A which is made up as follows:

YELLOW TONER A (Working Solution)

Yellow Toner A No. 1	1 oz.	25 cc
Yellow Toner A No. 2	1 oz.	25 cc
Standard ferricyanide solution	1½ drams	5 cc

STANDARD FERRICYANIDE SOLUTION

Potassium ferricyanide	½ oz.	11 g
Distilled water	4 oz.	100 cc

This ferricyanide solution does not keep well after it has been mixed. It may be kept in the dark, but not for more than a few days.

In mixing the working solution for the Yellow Toner A, add No. 1 to No. 2 while stirring gently until any precipitate has been completely dissolved. This solution does not keep well when mixed and only sufficient should be

prepared for the prints then in process. After the print has been for about 15 minutes in the Yellow Toner A, the solution should be poured off into a graduate and 3 drams (10 cc) of Standard Hypo Solution added to every 2 ounces (50 cc) of working solution, and thoroughly mixed. After washing the print for 1 minute in running water, return it to the tray and pour the toner with its added solution of Standard Hypo back on to the print. This operation should be done quickly and the tray vigorously rocked for about a minute to minimize any streaking of the yellow image. After 3 minutes the solution is discarded, the print washed for 1 or 2 minutes in clear water and then immersed for about a minute in the Standard Hypo Solution diluted with about 3 parts of water. Do not keep the print more than 1 minute in this dilute hypo solution as the image at this stage is slightly soluble in hypo and a longer time may result in loss of highlight detail. Wash the film immediately for 20 minutes in running water, or in five or six complete changes of water.

After washing, the yellow image is immersed for about 2 minutes in the Yellow Toner B, used without dilution or additions, and then, after washing in running water for about 20 minutes, or in six complete changes of water in the tray, it is ready for assembling.

The three-color images are registered on a sheet of Chromatone Backing Paper, which is furnished by the Defender Company, which has been previously thoroughly soaked in water. Lay the backing paper gelatin side up, on a clean ferrotype tin, a sheet of glass, or a Masonite board, or on any other flat waterproof surface. The yellow image is placed first on the paper and squeegeed firmly into place and allowed to set for a few minutes. The red image is then placed on top of the yellow, carefully registered, and squeegeed firmly into place. The blue image is then superimposed upon the other two in the same manner, completing the color transfer.

The print is now allowed to remain in the air until the surface has dried to some extent. It is then placed upon a piece of rigid, hard, waterproof material. Masonite tempered hard board is admirably suited for this purpose. The board should be enough larger than the print so that the print can be taped down on to it with ordinary craft gum tape which is moistened and stuck on to the board, overlapping on to the print about $\frac{3}{16}$ inch on all four edges. Do not let the gum tape be too wet or the gum will ooze between the print and the board making it difficult to remove the print, and if the prints have been assembled emulsion side up, the excess gum solution will tend to bleach the blue-green layer.

The print will dry rapidly stretched absolutely flat, and it can then be loosened from the board by carefully inserting a sharp knife through the tape under the edge of the print and running it around the print.

If the print has been assembled collodion side up, spotting and retouching can be easily done with transparent water colors while the print is still wet. Once the print has become dry, spotting is much more difficult.

If the print is assembled emulsion side up, transparent water colors may be used for spotting and retouching but larger areas can be tinted by using weak solutions of basic dyes. Transparent oil colors can be used as in tinting black-and-white prints.

Chromatone prints assembled collodion side up, dry with a very high gloss. If assembled emulsion side up, they have a luster which is greater in the highlights than in the shadows. A mat finish can be obtained if the prints are assembled collodion side up by gently rubbing the surface with fine, dry pumice powder, or by spraying with a mat lacquer. If the dry, finished print, assembled gelatin side up, is sprayed with an airbrush with a 4 per cent solution of gum arabic, the darker shadows become transparent and the whole surface assumes a very pleasing semi-mat surface which can be made more glossy by continuing the treatment.

Rougher surfaces may be obtained by using any regular rough-textured photographic papers instead of the Chromatone Backing Paper. Simply fix the paper without exposure in a hypo bath containing no hardener, and thoroughly wash it. A weak solution of gelatin must be flowed over the paper at the time of assembly and it is desirable to use the same solution between the assembled strip film layers. The gelatin solution will vary from 2 to 5 per cent depending upon the roughness of the paper, the rougher surfaces demanding more gelatin.

The collodion itself has a faint yellow tinge and when three emulsions of it have been superimposed, the whites are likely to show traces of this color. This may be remedied by removing the collodion from each print after it has been placed upon the paper backing. Squeegee the yellow print face down on the backing paper, tape it down on a Masonite board with gum tape and dry it for 30 minutes. Flow enough acetone over the print to cover it evenly and allow it to stand for 1 or 2 minutes to soften the collodion and then run a flat rubber squeegee lightly over the surface. This will remove a considerable part of the collodion, but a second and third application of acetone is usually needed. The red print is next registered over the yellow and allowed to dry for 30 minutes when the collodion is removed with acetone as before. The blue-green print is then registered over the yellow and magenta, squeegeed and allowed to dry for an hour or more to make sure that all the emulsions are firm when the acetone is applied for the third time, to remove the base from the blue-green print. A wad of cotton saturated with acetone is rubbed thoroughly over the surface to remove all traces of collodion. This method of assembly leaves the prints absolutely flat with no tendency to curl.

If negatives are too hard to make good Chromatone prints, they may be greatly improved by masking them with thin positives. In any case, negatives may deliberately be made more contrasty than normal and then masked to give better balance or increased brilliancy of the greens and reds. This method was first suggested by Mr. H. Murray of the Eastman Kodak Com-

pany. Make three thin positives by contact from the red record negative (blue-green printer) on a slow plate. One mask is now registered and bound by Scotch tape to each of the separation negatives. Each positive should be approximately one-third the density range of the negatives, which may be checked by superimposing the three masks and comparing the neutral scales with those of the negatives. Negatives to be used for this purpose should be developed about one-third longer than normal to give them enough contrast after masking to make successful prints, or normal negatives can be intensified for this purpose.

FILM DEVELOPER FOR POSITIVE MASKS

Water (about 120° F.)	96 oz.	3600 cc
Metol	115 gr.	7.8 g
Sodium sulphite	13 oz.	390 g
Hydroquinone	300 gr.	20 g
Water to make	128 oz.	4800 cc
Borax (crystals)	115 gr.	7.8 g

Develop $2\frac{1}{2}$ to 3 minutes at a temperature of 70° F.

WASH-OFF RELIEF.—In the Eastman Wash-Off Relief process, color prints are obtained by printing from each of a set of separation negatives on to separate Eastman Wash-Off Relief films. These films are then bleached and the soluble gelatin washed out, leaving relief images in hardened gelatin on the supports. These are fixed in hypo and thoroughly washed and then dyed in colors complementary to the color of the taking screen under which the respective negatives were made. These colors are transferred by imbibition to paper, each dyed relief image being squeegeed in turn on to a wet paper bearing a mordanted gelatin coating to which the color “migrates.”

Exposure.—The Eastman Wash-Off Relief films are printed, either by contact or by projection, through the back of the film, using a Wratten No. 35 filter over the light source whether printing by contact or projection. The exposure time is practically the same as for a fast bromide paper without a filter, and if the negatives are properly balanced, the exposure should be the same for all three colors. The exposure should be long enough to slightly gray the highest light where detail is desired, but not long enough to go through to the face of the emulsion, which would make the entire film insoluble.

Development of the Silver Image.—Develop for 5 minutes in Eastman D-11 at 65° F., under an Eastman O or OA safelight.

DEVELOPER D-11

Water (about 125° F.)	64 oz.	2000 cc
Elon	60 gr.	4 g
Sodium sulphite	10 oz.	300 g
Hydroquinone	1 oz., 85 gr.	36 g
Sodium carbonate	3 oz., 145 gr.	100 g
Potassium bromide	290 gr.	20 g
Water to make	128 oz.	4000 cc

The films are most conveniently developed all together in a tank so that they will receive identical treatment. If they are held in Eastman Film Developing Hangers No. 2, they can be manipulated in this and succeeding operations without being touched by the hands while wet, so that the warmth of the hands will not injure the film. Each film should be lifted completely out of the solution once each minute during development, and then replaced in the solution.

After development, without fixation the films are washed in the dark for 10 minutes. Washing must be thoroughly done, however, in this time. Keep the films continuously agitated, or in a rapid stream of water, and lift them completely out of the water and replace about once each minute.

The process may be interrupted after development by rinsing the films and then fixing them in Fixing Bath F-24, washing for 10 minutes and drying, after which they can be examined in full daylight. If the temperature of the wash water is above 70° F., or if the water is extremely soft, or alkaline, this intermediate drying is recommended to eliminate swelling of the gelatin, but they need not be fixed if they are dried in the dark.

FIXING BATH F-24

Water (about 125° F.)	16 oz.	500 cc
Hypo	8 oz.	240 g
Sodium sulphite	145 gr.	10 g
Sodium bisulphite	365 gr.	25 g
Water to make	32 oz.	1000 cc

Bleaching.—In the continuous process, after development and washing, the films are immersed, still on the hangers, in a tank of Bleaching Solution R-10a which should be made ready during the washing of the films.

WASH-OFF RELIEF BLEACHING SOLUTION R-10a

Stock Solution A

Water	16 oz.	500 cc
Ammonium bichromate	290 gr.	20 g
Sulphuric acid, C.P.	1 dram	4 cc
Water to make	32 oz.	1000 cc

Stock Solution B

Sodium chloride (table salt)	1½ oz.	45 g
Water to make	32 oz.	1000 cc

For use take 1 part solution A, 1 part solution B, and 6 parts water.

The images should be bleached until they appear a faint brown color, which will generally take about 2 minutes. The room lights may be turned on as soon as the films are completely immersed in the bleaching solution. The hangers should be completely lifted out of the bleach about every 10 seconds and immediately replaced. The bleaching solution is discarded after use.

Developing the Reliefs.—The reliefs are developed by hanging the films in a tray of water at 110° F. Lift the films completely out of the water and

replace about once every 10 seconds so that the melted emulsion may drain from the film. Take care that no part of the relief image rubs against the side of the tank, the hangers, or other film, which would damage the relief. At the end of 1 minute lift the films out, drain them, and transfer them to a fresh tank of water at the same temperature. The films are washed in this manner in four changes of water, all at 110° F., with gentle agitation. At the end of 4 minutes the films are lifted, drained, and placed in the Special Fixing Bath F-24 for about a minute, after which they are given a thorough 5 minute wash. Use no other fixing bath than this special one, given above.

Clearing (optional).— The faint brown residual image now remaining on the film does no harm in the transfer process, but the dyed reliefs are more easily judged if it is removed by immersing for 1 minute in Permanganate Reducer Formula R-2, washing for 3 minutes, and then clearing in the Non-Hardening Fixing Bath F-24 for 1 minute. The film is then given another 5 minute washing and if the wash water is hard, a final short rinse in distilled water is advisable.

PERMANGANATE REDUCER FORMULA R-2

Stock Solution A

Water	32 oz.	1000 cc
Potassium permanganate	1 $\frac{3}{4}$ oz.	52.5 g

Stock Solution B

Water	32 oz.	1000 cc
Sulphuric acid, C.P.	1 oz.	32 cc

For use take 1 part of stock solution A, 2 parts of stock solution B, and 64 parts of water. When preparing stock solution B, always add the acid slowly to the water while stirring the water rapidly. *Never add the water to the acid*, or the solution may boil over and spatter on the hands or face, causing serious burns.

Drying (optional).— The washed films may be dyed without drying but they will take up more dye in this condition and give a color print of higher contrast and shadow density than if they had been previously dried, hence if the reliefs are used for imbibition prints and then dried, and kept for making later prints, the later prints will be softer in quality. The remedy is to dry the prints before dyeing them the first time, or to add more acetic acid to the dye solutions in making subsequent prints, as is described later. Let the films dry naturally in a cool current of air. The use of hot air or alcohol for drying the films will cause uneven shrinkage of the film support and faulty register of the images.

Dyeing the Reliefs.— The Eastman A (blue-green), B (magenta), and C (yellow) dye solutions are dissolved in boiling distilled water according to the directions stated in the folder which accompanies them. The addition of formalin solution at the rate of 1 $\frac{1}{4}$ drams per 16 ounces (5 cc to 500 cc) to the dye solution prolongs its life by preventing the growth of mold.

After the dyes are dissolved, the solutions are cooled to 68° to 80° F. and then filtered through rapid filter papers. The temperature of the solutions should be maintained within this range. The trays used for the dye solutions should be clean and of glass or perfect white enamel. They should be kept covered to prevent the access of dust and the evaporation of the dye solutions.

The three reliefs are dyed for at least 30 minutes in the respective dye solutions, with frequent but not necessarily continuous rocking of the trays. After use, the dyes may be transferred to clean stoppered bottles and kept for future use.

After dyeing for 30 minutes, and a longer time does no harm if it is uniform with all the films, each relief is rinsed separately in two changes of dilute acetic acid to remove surplus dye from the surface and to set the dye taken up by the relief image. The film should be quickly and completely covered by the acid to secure uniform results all over the film, and the tray must be continually rocked in both directions.

If the reliefs are to be used for transparencies, use two changes of a $\frac{1}{2}$ per cent solution of acetic acid for the rinse. If the reliefs are to be used for imbibition prints, two changes of a 1/10 per cent solution of acetic acid in distilled water is employed for the blue-green and magenta dyed reliefs, and two changes of a $\frac{1}{2}$ per cent solution for the yellow dyed relief.

After rinsing, all three dyed reliefs are placed in a covered tray containing a 1/10 per cent solution of acetic acid, where they are kept until needed for the imbibition transfer.

While still wet with acetic acid, the dyed reliefs are superimposed in register on the bottom of a white porcelain tray and if they are to be used for imbibition prints, they are judged by inspection for their balance and density. If the reliefs are to be used for transparencies, they are lifted in register from the tray and inspected and judged by transmitted light.

Finishing Transparencies.—When a set of reliefs have been found to be correctly dyed for transparencies, the $\frac{1}{2}$ per cent solution of acetic acid is drained from the films. There is no need to rinse them in water since the dilute acetic acid readily evaporates. The films are dried separately in cool dry air, and then registered and bound between clear glass. The mat surface of the films obviates any necessity for groundglass or opal glass. For projection in a lantern, greater brilliancy is obtained if the gelatin surface of each of the three unbound films is flowed with Varnish Formula V-1 and allowed to drain off at one corner so as not to produce a thick layer. It will take several hours for the varnish to dry thoroughly before the films are bound together.

VARNISH FORMULA V-1

Gum sandarac	365 gr.	25 g
N-Butyl alcohol	6 $\frac{1}{2}$ oz.	200 cc
Castor oil	1 $\frac{1}{4}$ drams	5 cc
Oil of lavender	$\frac{1}{4}$ dram	1 cc

Warm the gum and alcohol together until the gum has been entirely dissolved (caution: Butyl alcohol is inflammable and should not be heated over an open flame). Filter the solution through fine lintless cloth, add the castor oil and the oil of lavender, mix thoroughly and cool before using. The oil of lavender may be omitted if the odor of castor oil is not objectionable.

Making Imbibition Transfers to Paper.—A special paper with a gelatin coating called *Trade 867* is available as the final paper support for the color prints, but any photographic paper except those with a rough surface may be used by fixing it in a fresh solution of Special Fixing Bath F-24 and washing it. The paper should be 1 or 2 inches larger than the dyed positive in each direction, to leave a safe edge all the way around the picture.

The fixed and washed photographic paper or the special gelatin-coated paper, whichever is used, is first bathed for 5 minutes in the aluminum sulphate paper-mordanting solution.

ALUMINUM SULPHATE MORDANTING SOLUTION M-1

Solution A

Aluminum sulphate	6½ oz.	200 g
Water to make	32 oz.	1000 cc .

Solution B

Sodium carbonate	1 oz., 145 gr.	40 g
Water to make	16 oz.	500 cc

Add solution B to solution A with constant stirring until the white precipitate which is at first formed, is dissolved. If a trace should remain, it can be filtered out with a rapid filter paper.

After mordanting, the paper is washed for 5 minutes in running water followed by a 5 minute bath in a buffer solution of 5 per cent sodium acetate, followed by another 5 minute washing. It may be used immediately in the wet state, or it may be dried and kept for future use.

If the paper is dried, it is first soaked in water for 5 minutes and then laid gelatin side up on a larger sheet of plate glass. The paper is stretched to its maximum so that it will not change during the imbibition transfer process and cause faulty register, by covering it with a sheet of Kodaloid and squeezing it with considerable pressure in each direction. The Kodaloid is then removed from the paper, which is placed upon a damp blotter and the first dyed relief placed upon it immediately before the paper has had time to dry. Best results are obtained by transfer in the sequence: magenta, blue-green, yellow.

The magenta-dyed relief is taken from the 1/10 per cent acetic acid bath and while still wet, placed image side down on the prepared paper. The paper is held with the fingers of one hand while a wet squeegee is run lightly over the relief in both directions to expel water and air. Successive strokes of the squeegee are given with firmer pressure until finally the squeegee is used with as much force as possible to secure intimate contact. A second sheet

of plate glass is then placed over the relief film which is left in contact until all the magenta dye has transferred from the relief to the paper. This will take from 10 to 30 minutes depending upon the shadow density. Lift one corner of the relief carefully from the paper to see if all the dye has transferred. If it has not, it should be left longer under pressure. Greater pressure will shorten the time for transferring the dye and a letterpress can be used to good advantage. The process should be watched, as the prints should be left in contact with the paper only long enough to completely transfer the dye.

After the magenta transfer is complete, the relief film, now denuded of color, is stripped from the paper and the blue-green dyed relief is removed from the acetic acid and registered over the magenta image on the paper. Register is facilitated by wetting a sheet of 3/1000 inch Kodaloid and laying it over the magenta image on the paper so as to cover all of the area to be occupied by the relief film except the safety margin at one end. The blue-green relief image is registered over the magenta image on the paper with the sheet of Kodaloid between. When it is accurately registered, by holding down the end which the Kodaloid did not cover, the Kodaloid can be slipped out and the second print plate squeegeed firmly into contact as before. It is then covered with a sheet of plate glass and left for a sufficient time for the color to migrate as in the first transfer. This will take about the same length of time.

The yellow is then transferred in the same way, but this will usually take only from 5 to 10 minutes. After removing the yellow relief, the paper bearing the three-color print is placed between two dry blotters, and dried. If desired, prints on glossy paper may be dried by squeegeeing them while still wet on to ferrotype tins in the usual manner, and letting them dry there.

Corrective Treatment.—If the appearance of the dyed reliefs when assembled in register is not satisfactory, some corrective methods may be applied before proceeding with the process.

Contrast can be increased by adding a small quantity at a time of 5 per cent acetic acid solution to the dye solution and soaking the dyed relief again in it. Start by adding a small amount of acid and increase slowly until the desired effect is obtained, but always hold the relief out of the solution while the acid is being added and mixed. To reduce contrast, the dyes can be removed by bathing the reliefs in a 1 per cent solution of ammonia followed immediately by a bath in plain water, after which they may be re-dyed in a dye solution containing less acid than was previously used. Contrast may also be increased by removing the dye and re-dyeing the relief in a more diluted dye bath. The bath should be diluted with not more than an equal amount of water or irregular results will occur. With the quicker dye bath, the staining of the films will take proportionately longer.

Masking.—Up to the present writing, no dyes have been evolved which will perfectly absorb one primary color and reflect the other two, as theory

demands in subtractive color processes. As a result, prints made without color correction of some sort show lack of saturation through dilution with white in the magentas, yellows, and reds. This correction has long been made by photomechanical workers by "color etching." Much the same results have been achieved photographically by the use of suitable masks in connection with the separation negatives, a process developed by Eastman Kodak Company.

According to this effective method, three positive prints of low contrast are made, two from the red-filter negative and one from a yellow-filter (K3) negative. One print from the red-filter negative is superimposed in register with the green-filter negative so as to form a mask when exposing the magenta printing positive. This mask adds to the density of the green-filter negative in proportion to the amount of cyan printed in various parts of the picture, and, hence, subtracts from the density of the magenta printing positive in those same portions. The low-contrast yellow-filter positive is used as a mask for the blue-filter negative when exposing the yellow printing positive. Hence, it subtracts from the density of the yellow printing positive in proportion to the amount of cyan and magenta printed in various portions of the picture. The second low-contrast red-filter positive is used as a mask in exposing the cyan printing positive in order to make the contrasts of the three positives more nearly equal, since the masks flatten the magenta and yellow images in the scales of grays. In color photography, the adjustment may also be made, however, by increasing the contrast of the magenta and yellow positives. Whichever method is used, the relative proportions of the three dyes in the scale of grays are the same as if no masking had been employed. However, in those portions of the picture where relatively more cyan is printed than in the grays, relatively less magenta and yellow are printed. Thus, the cyans, greens, and blues are more nearly rendered with their correct luminosities. Also, in those portions of the picture where magenta and yellow are printed with little or no cyan there is little or no masking effect. Hence, as a result of the increase in contrast in the magenta and yellow images, these portions actually receive more magenta and yellow relative to the scale of grays than without masking. Thus, the saturation of magentas, yellows, and reds is increased.

Semiautomatic Masking Method.—The method of color correction just described, originally intended for photomechanical reproduction, has been found to work satisfactorily in color photography by the Eastman Wash-Off Relief Process. It necessitates, however, the making of three extra positives as masks, and developing these to predetermined contrasts. A different masking method has been worked out, especially applicable to color photography, which does not require making extra positives, and is more or less automatic in operation, and for this process a patent has been applied for by Eastman Kodak Company. While this method can be employed in a number of different

processes of color photography, it will be here described as applied to the Eastman Wash-Off Relief Process.

According to this "automatic" masking method, the red-filter negative is first printed on Wash-Off Relief Film in the ordinary way. This film is then carried through the relief process and dyed in the cyan or A dye. After the film has dried, the cyan image is placed in register with the green-filter negative. Another print is then made through both the green-filter negative and the dyed cyan positive. This print is carried through the relief process and dyed magenta. After this film has dried, both the cyan positive and the magenta positive are placed in register with the blue-filter negative. The third print is made through the negative and the two masks. The three negatives may be developed to the same gamma, and the increase in contrast of the magenta and yellow images, necessary to preserve the scale of grays, is preferably effected in dyeing the relief images.

Since the relief film is sensitive only to blue-violet light, the density of the yellow image is reduced in proportion to the density to blue-violet light of the magenta and cyan images used as masks for the blue-filter negative. However, this density to blue-violet light of the magenta and cyan images is precisely the thing for which the correction of the yellow image is made. Thus, the automatic nature of the color correction is obvious.

To correct the magenta image for the density to green light of the cyan dye, the print through the green-filter negative and the cyan positive should theoretically be made by green light, which would require a green-sensitive relief film. In practice, however, it has been found that considerable improvement is obtained even by depending upon the density to blue-violet light of the cyan image in printing from the red-filter negative on the regular relief film which is sensitive only to blue-violet.

DUXOCHROME OR COLORSTIL. — Duxochrome is a proprietary process similar to Eastman Wash-Off Relief except that the color is incorporated in the film during manufacture instead of having to be incorporated in it during the processing. It is marketed in America under the name Colorstil. Three separation negatives are printed through the transparent support on to films which contain in their emulsion the complementary colors. These films are developed in a tanning developer and then placed in warm water where the untanned gelatin is washed away, leaving colored silver images in relief. The silver is then removed by Farmer's reducer, leaving only pigment images in relief on the films. These pigment images are then transferred and superimposed in register on a paper support. The process is very easy to handle, being one of the simplest of the color processes, but the prints are likely to be somewhat granular.

PINATYPE was the prototype of imbibition processes, being introduced in 1906 by the German dye firm Lucius and Brunning, based upon methods proposed by Edwards in 1875.

"Print plates" were made by making positive transparencies, from three separation negatives, on gelatin-coated plates sensitized with bichromate. These plates were stained with tricolor "Pina" dyes, the parts not hardened by light action absorbing the maximum amount of dye, which was transferred to a support of gelatin coated paper. The process was long and somewhat involved, and it has been supplanted by the more easily worked Wash-Off Relief Process.

Jos Pé process which is similar to Pinatype was introduced by the firm of Jos Pé in Hamburg in 1926. It combines both relief and imbibition, depending upon varying depths of colorless gelatin to imbibe different amounts of dye which is then transferred to paper. All the materials for this process, including color separation cameras, are furnished by its sponsors.

AUTOTYPE-DYEBRO is a process similar to tricolor Carbro, except that the Dyebro carbon sheets that are placed in contact with the bromide prints do not contain the primary colors, but give the outline of the images only in faint gray. These images are transferred to sheets of unwaxed celluloid upon which they are developed and then dyed in the primary colors by the use of special Dyebro dyes. The dyed images are then transferred from the celluloids and superimposed in register upon a prepared paper base, to form a colored print.

TWO-COLOR SEPARATION. — A great many processes have been devised for reproducing color by two separations, but with a small degree of success, among other difficulties being the impossibility of getting a pure yellow, but some of them have been used quite extensively in motion picture photography on account of their convenience and saving of expense.

TECHNICOLOR was first marketed as a two-color relief process for motion pictures, but was later developed into a three-color imbibition process, the film being exposed in special cameras devised for the purpose, and being easily duplicated to meet the needs of the professional motion picture industry.

CHAPTER XXIII

STUDIO AND DARKROOM HELPS

BACKGROUNDS.—Cotton sheeting is the best material and it can be obtained up to 108 inches wide. Make a wooden stretcher of the required size and lay it flat on the floor, and having the right-hand bottom corner of the material held down to the corresponding corner of the frame, stretch the material quite taut, and nail down the top left-hand corner to the edge of the frame. Drive the tack through a $\frac{1}{2}$ inch square of cardboard and the material at the same time, at both corners. Tack the other corners in the same way. Then tack the center of the top and bottom edges, then the sides, pulling the material taut before putting in each tack. The result should be free from wrinkles. The sheeting must then be sized. For this rub 1 part of starch into a cream with 3 parts of water, and boil until a clear solution is formed. Apply this with a stiff brush to the material, and stand the frame on end to dry. The background may be painted with commercial distemper powders, such as kalsomine, or with a paint mixed as follows:

Whiting	24 parts
Powdered glue	8 parts
Molasses	12 parts
Water	160 parts

Soak the glue in the water for some time, add the molasses and melt with heat, and stir in the whiting until a smooth cream is obtained. Divide into 3 parts. For colors, obtain the following dry water-color pigments: ivory black 2 parts, ultramarine 1 part, red ochre 1 part. Mix the three pigments together and divide into 6 equal parts. To one-third of the glue solution add 1 part of the pigment; to another third of the glue add 2 parts of the pigment; and add the remainder of the powder to the rest of the glue. This will give three distempers of different shades.

The cloth may also be painted, without sizing, with casein paint.

Backgrounds may be made of dry canvas tightly stretched on a wooden frame, then well wetted, a mixture of dextrine and color sifted over the surface from a fine sieve, and the surface then worked over with a stiff brush. The colors mentioned above may be used, or any dry powdered color such as is used for house decoration. The colors are much lighter after drying. For gray and black backgrounds, double size, which is used by paperhangers, may be melted in a saucepan, slightly thinned down, and lampblack and whit-

ing, previously mixed to the required tint, added. Two coats should be given with a stiff brush, the second being applied with the brush strokes in the opposite direction to the first.

PHOTOGRAPHING MACHINERY. — Bright parts may be dulled by being painted over with a thin cream of white lead and turpentine, darkened by the admixture of lampblack to give a gray. Dabbing the surfaces with a lump of putty will often be sufficient.

MEMORIAL STONES AND BRASSES. — If the surfaces of the stones are swept clean, and strong side lighting used, the lettering and carvings will be thrown into relief. Wetting the stone frequently brings out indistinct lettering. In the case of brasses, rubbing with whiting, avoiding any deposit in the letters, is useful, as is also side lighting. Rubbings, obtained by placing a sheet of paper over the brasses and rubbing with a soft pencil or charcoal, may also be used.

SILVERWARE AND GLASSWARE. — Hollow silverware may be filled with ice or very cold water; then in a warm, damp room the outer surface will become dewed. Dabbing the surface with putty will also kill all reflections. Or the object may be placed inside a tunnel of tissue paper (or of tracing cloth which gives more even illumination) against a black background, so that the light reaching it has to pass through the paper, and falls in one direction only. Glassware may be treated like silver, or hollow cut glass vessels may be filled with a non-actinic solution, such as ink or dye.

In another method for glassware, the objects are lighted at appropriate angles from the front, with amber filters, such as stage lighting gelatins, over the lights. A spotlight or a blue Mazda bulb is used to focus a spot of light across the pieces from behind. The blue light emphasizes the cuttings and facets with strong relief.

OBJECTS UNDER GLASS. — If it is desired to show the glass cover, give about one-quarter of the whole exposure to the object with the glass in position; then remove the glass, and complete the exposure.

TO BLACKEN METAL MAGAZINE HOLDER SHEATHS. — Remove any rust with emery paper, wash in washing soda solution and then immerse briefly in very dilute sulphuric acid, after which blacken with a mixture of equal volumes of solutions A and B:

<i>Solution A</i>		
Hypo	1 oz.	100 g
Water	3 oz.	300 cc
<i>Solution B</i>		
Lead acetate	1 oz.	100 g
Water	10 oz.	1000 cc

When the blackening is complete, the sheaths are removed and drained, then dried by gentle heat.

TO BLACKEN BRASS. —

Copper nitrate	200 gr.	208 g
Water	1 oz.	500 cc

Dissolve and add the following solution:

Silver nitrate	200 gr.	208 g
Water	1 oz.	500 cc

Clean the metal thoroughly, immerse in the mixture, and then heat; repeat if necessary.

Another method is to immerse in the following:

Copper carbonate	384 gr.	50 g
Ammonia	192 minims	25 cc
Water	16 oz.	1000 cc

Clean the metal and immerse until black, then wipe dry and lacquer. This attacks soft solder. Solution of antimony chloride (butter of antimony), brushed on, gives bronze colors. Boiling the metal in a solution of potassium sulphide (liver of sulphur) until sufficiently black, then rinsing, drying, and smearing a little oil over it, gives better results than the above silver method.

TO BLACKEN WOOD. —

Borax	1 oz.	62.5 g
Glycerin	1 oz.	62.5 cc
Shellac	2 oz.	125 g
Water	16 oz.	1000 cc

Boil until completely dissolved and add water to restore the original bulk, then add:

Nigrosine, water soluble	2 oz.	125 g
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Stir until thoroughly dissolved, and paint the wood two or three times. This is not as satisfactory as the following, in which the aniline black is chemically formed in the wood.

Cupric chloride	538 gr.	70 g
Potassium bichromate	538 gr.	70 g
Hot water	16 oz.	1000 cc

The wood should be freed from grease, then painted with this solution and allowed to dry well, then painted with:

Aniline hydrochloride	2½ oz.	140 g
Water	16 oz.	1000 cc

Allow to dry, wipe off any yellow powder that forms, and repaint with these solutions until black enough. As a rule, two coats are sufficient, as the color deepens in a day or two. Then rub well with boiled linseed oil and leave to dry.

BLACK FOR WOOD OR METAL. — Use vegetable black mixed with terebene or turpentine. When used on the inside of the bellows, the black is made into a stiff paste with raw linseed oil and then thinned down with turpentine.

BLACK FOR CAMERAS. — This may be used for wood or leather, inside or out:

Nigrosine, spirit soluble	37 gr.	2.5 g
Bismarck brown	10 gr.	0.65 g
Alcohol	50 minims	3 cc
Aniline	1 oz.	29 cc

Heat the dyes with the alcohol until dissolved, and then add the aniline; apply with a brush and dry before a fire or in the sun. For a dead mat varnish, lampblack may be rubbed up with gold size or shellac varnish, using as little of the liquid as possible; then thin down with turpentine.

TO BLACKEN ALUMINUM. — Clean perfectly free from grease by washing in soda solution, wash well, and immerse in:

Ferrous sulphate	1 part
Arsenious acid	1 part
Hydrochloric acid	12 parts
Water	12 parts

When the color is deep enough, dry with fine sawdust, and then lacquer. This solution is intensely poisonous.

INK FOR BOTTLES. — The following formula gives a waterproof ink, and either black or white ink can be made by using lampblack or zinc white:

Copal (powdered)	92 gr.	12 g
Oil of lavender	16 oz.	1000 cc

Dissolve by heat and stir in, for black:

Lampblack	9 gr.	1.2 g
Indigo	4 gr.	0.5 g

Or, for white:

Zinc white	11 gr.	1.5 g
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Apply with a fine brush.

LACQUERING BRASS. — As in blackening, success requires attention to details and proper pickling. Handle the articles with a piece of clean rag. The brass must be hot so that the lacquer smokes and fumes, but does not burn, when applied with the tip of the brush. Keep the brush flat and remove excess lacquer from it by a wire fastened across the mouth of the lacquer jar. After one coat, dry thoroughly over a stove or a burner, and repeat. Lacquer ap-

plied too thick is lumpy and streaky and when too thin shows iridescent colors. Alcohol is the best thinner.

Turmeric	3 drams	36 g
Saffron	8 gr.	1.6 g
Hot alcohol	10 oz.	1000 cc

Infuse and shake frequently. Decant the solution and add:

Gamboge	3 drams	36 g
Gum sandarac	1 oz.	96 g
Gum elemi	1 oz.	96 g
Dragon's blood	$\frac{1}{2}$ oz.	48 g
Seed lac	$\frac{1}{2}$ oz.	48 g

A simpler formula is:

Alcohol	10 oz.	1000 cc
Gamboge	$\frac{1}{2}$ dram	6 g
Shellac	$\frac{1}{2}$ oz.	48 g

To keep lacquer fresh and bright-looking, polish with a trace of turpentine and beeswax furniture polish. Lacquers of the celluloid varnish type can also be purchased, either colorless or of golden tints.

RENOVATING BRASS STOPS. — Brass Waterhouse stops and similar articles that need blackening where they have worn bright should be treated with ammonia to remove grease and finger marks, and then pickled in 32 ounces of 10 per cent nitric acid to which is added cautiously, a few drops at a time, 1 ounce of sulphuric acid. Failures are usually due to lack of care in cleaning and pickling. Suspend the articles in the liquid from a brass wire and after a short time, dry by shaking up in a box half-filled with sawdust. When properly clean, they must be blackened.

To render them a good black, dissolve some scrap copper in nitric acid until the acid will take up no more. Dip the cleaned brass piece in this liquid and burn it off dry in a blue gas flame such as that of a Bunsen burner or a gas stove.

Very thin brass like that used for a pinhole aperture, and some iris leaves of lenses (brass), may be treated with a cold water solution of platinum bichloride, 10 to 20 grains per ounce (0.2 to 0.4 g to 10 cc). Apply this to the cleaned brass and the edges of the pinhole with cotton on a glass rod.

BLANCHARD BRUSHES, often referred to in photographic literature, are made by wrapping two or three folds of cotton flannel over the end of a strip of glass and securing them with a rubber band. They are used for applying washes and sensitizing solutions. After use, the cloth is discarded and the glass washed so that a new brush is made each time one is wanted and there is no danger of contamination from previous use as in the case of bristle brushes which are often difficult to make thoroughly clean.

BENCH COATING. — A dressing for bench tops which will stand the wetting and slopping of chemicals:

Asphalt	4 oz.	400 g
Pure rubber	30 gr.	7 g
Naphtha	10 oz.	1000 cc

FIREPROOFING FABRICS. — Soak the material in:

Alum	8 oz.	80 g
Ammonium carbonate	2½ oz.	25 g
Boric acid	1½ oz.	15 g
Borax	1¾ oz.	17.5 g
Water	100 oz.	1000 cc

Another formula is:

Boric acid	200 gr.	11 g
Ammonium phosphate	4 oz.	100 g
Water	40 oz.	1000 cc

Or the following may be used:

Borax	12 oz.	150 g
Magnesium sulphate	9 oz.	112.5 g
Water	80 oz.	1000 cc
Starch	2 oz.	25 g

Boil the starch with the water and add the salts. Immerse the fabric in any of the above mixtures until thoroughly soaked, then dry and iron.

A strong solution of aluminum acetate, specific gravity 1.050, diluted with forty times its volume of water may be used, in which the material should be immersed for 24 hours and then dried in the shade.

Washing fireproofed materials makes it necessary to re-treat them.

FLEXIBLE LANTERN SCREEN. — A flexible screen which can be rolled up for easy portability is made by painting cotton cloth with:

Glycerin	16 parts
White glue	16 parts
Zinc oxide	32 parts
Hot water	10 parts

All are to be weighed. Dissolve the glue in the hot water and add the zinc oxide, ground up with the glycerin. Apply hot to the screen. A screen 10 feet square requires about 160 ounces. This screen can be rolled, but not folded, as folding it would cause it to crack. It is most conveniently operated by tacking it to a window-shade roller whose brackets have been fastened on to a strip of wood. The strip of wood should be provided with screw eyes by which it can be suspended. The screen can then be pulled down like a window shade for use, and rolled up again by the spring in the fixture, so that it can be conveniently stored when not in use.

CLEANING UTENSILS.—Apparatus used for photographic chemicals and solutions becomes discolored and coated with decomposition products. This often does no harm if the utensils are always used for the same purpose but it is better to clean them each time they are used. Enameled trays are best cleaned by washing them with several changes of water and wiping with a clean cloth immediately after use. This will usually keep them in good condition for a long time without the constant use of the harsh solutions which are commonly used for this purpose. Strong oxidizing solutions like the ordinary acid bichromate tray cleaner, etch the enamel slightly every time they are used and will eventually destroy the glaze and allow solutions to penetrate to the iron base with harmful or even disastrous results to some photographic processes. Such cleaning agents should be used on trays only occasionally, when stains cling to the surface of trays too tenaciously to be removed by milder methods.

Oxidized Developer Stains can usually be removed by washing with soap and water applied with a cloth, but if they are too stubborn they may be removed by the use of the following:

BICHROMATE TRAY CLEANER (Eastman TC-1)

Water	32 oz.	1000 cc
Potassium bichromate	3 oz.	90 g
Sulphuric acid, C.P. (concentrated)	3 oz.	90 cc

Add the acid slowly, with stirring, to the bichromate solution. Pour the solution into the container that is to be cleaned and rinse it around so that it has access to all parts, then pour it off and rinse with several changes of water until all yellow stain has disappeared. This solution should not be used with chromium-plated apparatus as it tends to destroy the copper undercoating. Chromium plate and stainless steel utensils should be cleaned with a brush and scouring powder.

Other solutions that are useful for cleaning developer stains are a 1 per cent potassium permanganate solution followed by 5 per cent sodium bisulphite to remove the manganese stain; 40 per cent sodium hydroxide (caustic soda); or any of the strong mineral acids like sulphuric, hydrochloric, or nitric. After the use of any cleaning agent the utensil should be thoroughly washed in water.

Sulphur and Silver Sulphide Deposits are often formed on vessels containing a hypo alum toning bath, or a fixing bath that has sulphurized. A *sulphur deposit* is dissolved in a hot 20 per cent solution of sodium sulphite, or a warm 10 per cent solution of tri-sodium phosphate (commercially sold as Oakite). The action may be hastened by adding glass beads or sand to the solution and shaking vigorously.

A silver sulphide deposit is removed by a 1 per cent solution of potassium permanganate, followed by a 5 per cent solution of sodium bisulphite to remove the manganese stain.

A 2 per cent solution of potassium cyanide is another good cleaning agent, but it is a deadly poison and must be used with care, and in a well-ventilated room on account of the poisonous fumes that it gives off. It should never be discarded into a sink where any acid is standing, and it should be followed by a large volume of water when it is poured down a drain.

Silver Deposits usually come from slight physical action in many developers, from silver intensifiers, or from an exhausted fixing bath. Such deposits may often be removed by Farmer's reducer or the iodine-cyanide reducer. More obstinate cases usually yield to the treatment of soaking for an hour in 10 per cent acetic acid (1 part glacial acetic acid, 9 parts water) followed by scrubbing with a brush in clean water. In extreme cases it may be necessary to dissolve the silver by soaking the utensil for 10 minutes or more in the acid bichromate tray cleaner (page 335) diluted with 2 parts of water. After removal from the solution, brush with a stiff brush. Use a glass or hard rubber tray as a container for the cleaning solution as it attacks enamel ware, and note the caution about chromium-plated ware. A boiling solution of 10 or 15 per cent tri-sodium phosphate is especially efficacious in removing a spongy layer of silver in gelatin on film hangers or clips. If they are badly corroded the deposits may be removed only by sandblasting.

SLIME, FUNGUS, MOLD. — A 4 per cent solution of calcium hypochlorite (bleaching powder or chloride of lime) is prepared and to this 10 per cent sodium carbonate solution is added until no more precipitate will form. When this settles, the clear solution is decanted to be used for a stock solution, diluted with 6 parts of water before using. Such a working solution is allowed to remain in a tank overnight, after scrubbing away as much slime as possible. More scrubbing and several good rinsings should follow.

Another formula for this purpose, known as Javelle water, is 1 pound of sodium carbonate and $\frac{1}{4}$ pound of chloride of lime, dissolved in 1 quart of hot water, the clear solution then being decanted off for use. Appropriately diluted, this will remove age and fox stains, most ink stains and some fruit stains from paper, linen, and white cloths. In stubborn cases, alternate baths of dilute Javelle water and 1 per cent oxalic acid or hydrochloric acid are needed. The action is slow, 15 minutes or so in each bath being needed. The final acid bath must be thoroughly washed out in running water.

STAINS ON HANDS. — For removing most developer stains, immerse the hands in the following solution:

PERMANGANATE STAIN REMOVER

Water	32 oz.	1000 cc
Potassium permanganate	$\frac{1}{2}$ oz.	15 g
Sulphuric acid, C.P. (concentrated)	75 minims	5 cc

Add the sulphuric acid to the permanganate solution while stirring rapidly. The permanganate dissolves with difficulty and solution may be hastened by

dissolving the crystals with violent shaking in part of the water which has been heated to about 180° F. (82° C.), then adding the rest of the water and allowing it to cool before adding the acid.

After bathing the hands in the permanganate solution, rinse them in water, and then in a 5 per cent solution of sodium bisulphite, or in a fresh acid fixing bath. If one treatment is not sufficient, rinse the hands and repeat, warming the bath if necessary for more efficient action. This treatment will remove almost all developer stains as well as stains caused by writing or stamping inks.

Silver stains, if slight, may be removed by the above treatment, but more obstinate stains, such as those produced by silver nitrate, may have to be removed by the following:

BLEACH BATH TREATMENT

Water	32 oz.	1000 cc
Potassium ferricyanide	1 oz.	30 g
Potassium bromide	1 oz.	30 g

After treatment, rinse the hands, then immerse in an acid hypo bath, then wash thoroughly.

STAINS ON CLOTHING. — While stains may readily be removed from clothing, there is always a danger that the stain remover may weaken the fabric, and a trial should always be first made on a small area to make sure that it does not attack the fabric or destroy the color.

Developer and Ink Stains, if upon *white* fabrics, may often be removed by treatment in a solution of hydrogen peroxide. Failing to secure results in this, soak the fabric in a 5 per cent solution of oxalic acid or acetic acid for 2 minutes, wash for 1 or 2 minutes, and then apply a saturated solution of calcium hypochlorite (bleaching powder) for 10 minutes. Wash, and if the stain is not completely removed repeat the acid and, if necessary, the hypochlorite solution, and then wash thoroughly. The acid and permanganate hand cleaner (see above) may be used for removing stains from clothing, but it always weakens the fabric more or less. None of the acid treatments should be used upon anything except cotton fabrics. The peroxide treatment is the only one that can be used with any degree of safety upon *colored* fabrics, but the acid treatments may be used with success if a preliminary test shows that they do not bleach out the color.

Silver Stains may be removed from *white* fabrics by the use of the bleach bath formula recommended (above) for cleaning the hands. A 1 per cent solution of potassium cyanide may be used for cotton fabrics but *not* for wool. Note cautions about the use of potassium cyanide given on page 123. For *colored* fabrics use the bleach bath with the potassium bromide reduced to $\frac{1}{4}$ ounce (7.5 g) for 10 minutes, wash for 2 minutes and then apply an acid fixing bath or plain 10 per cent hypo.

Dye Stains. — First try washing the fabric thoroughly with water, as many dyes are water soluble. Next try denatured or wood alcohol. If the stain is not removed by either of these treatments, *if the fabric is white*, immerse it in a 0.5 per cent solution of potassium permanganate containing about 0.25 per cent sulphuric acid. After rinsing off this solution, treat with 5 per cent sodium bisulphite to remove the manganese stain and then wash thoroughly in water.

If the fabric is *colored*, wet it with 3 per cent ammonia, and then wash it. If this does not remove the dye it probably cannot be removed without bleaching the color in the fabric.

Ink Eradicators as sold commercially usually consist of oxalic acid and hypochlorite and can be used for the removal of many stains if a preliminary test shows that they do not injure the fabric or the color.

Farmer's Bulletin No. 14, issued by the U. S. Department of Agriculture, and obtainable at five cents per copy from the Superintendent of Documents, Government Printing Office, Washington, D. C., contains many valuable hints on the removal of stains from fabrics.

STAINS ON NEGATIVES AND PRINTS are almost always caused by carelessness upon the part of the operator, the most usual causes being the use of solutions at too high a temperature, overworking a developer or fixing bath, lack of agitation, or insufficient fixation and washing.

Chemical treatment of a photographic emulsion to remove stain is always fraught with some risk and it should never be attempted without first making as good a copy of the original as possible. In the case of many stains on negatives the defect can be entirely obviated by copying through a suitable filter. This is notably true of yellow stains and the Wratten G filter.

If the stain is in the gelatin coating on the back of the negative, the simplest remedy is to remove this coating (see page 347).

White Stains. — A white scum usually consists of hypo crystals due to insufficient washing, and may be removed by additional washing. If the scum is insoluble in water it is probably a sludge of aluminum sulphite which may be dissolved by a 5 per cent solution of sodium carbonate, after hardening the film. This deposit is usually caused by the use of a highly alkaline developer without the use of a stop bath, or by lack of agitation when the film is first placed in the hypo. A fixing bath like Eastman F-5 (page 103) has little tendency to form this sludge.

A yellowish white stain on prints is usually caused by insufficient washing and is often removed by bleaching and redevelopment.

Yellow Stains. — Yellow oxidation stains are caused by the use of an old or discolored developer, too warm developer, lack of agitation, or, locally, by the projection of part of the material out of the solution while processing. The stain can usually be discharged by bleaching and redeveloping. Or a new negative may be made by copying through a Wratten G filter.

A yellow silver stain is caused by an old or exhausted fixing bath, or by insufficient agitation resulting in films sticking together and holding hypo and silver salts. This can rarely be completely removed by chemical treatment and the best remedy is to copy the negative on panchromatic film using a Wratten G filter.

Yellowish Brown Stains caused by iron rust or by decayed vegetable matter in the wash water, are usually removed by bleaching and redevelopment.

Blue Stains are caused by Prussian blue formed by the reaction of ferro- and ferricyanides with an iron salt and are usually traceable to defective coating on an enameled iron tray. Treat with 10 per cent potassium oxalate and wash thoroughly.

Dye Stains are either residual stains left in film after processing, or dyes that have accidentally come in contact with the film. A perfect negative can usually be made by photographing the stained negative with a proper filter. Bleaching and redeveloping usually removes the stain. Or it may be eliminated by bathing the film in 5 per cent ammonia or 10 per cent sodium sulphite and washing thoroughly.

BLEACHING AND REDEVELOPMENT. — Where this treatment is advised in the preceding notes, the following procedure is advised.

First bathe the film for 2 or 3 minutes in:

FORMALIN HARDENER (Eastman SH-1)

Formalin, 37 per cent formaldehyde solution	2½ drams	10 cc
Sodium carbonate	73 gr.	5 g
Water to make	32 oz.	1000 cc

Wash for 5 minutes and then bleach in:

STAIN REMOVER (Eastman S-6)

Stock Solution A

Potassium permanganate	75 gr.	5.3 g
Water to make	32 oz.	1000 cc

Stock Solution B

Sodium chloride (table salt)	2½ oz.	75 g
Sulphuric acid, C.P. (concentrated)	½ oz.	16 cc
Water to make	32 oz.	1000 cc

Use equal parts of solutions *A* and *B*, which should be mixed only at the time of use, as they keep well in separate solutions but not in combination. Be sure that the potassium permanganate is thoroughly dissolved, as any particles of it out of solution will cause blemishes on the negative.

Bleach for 3 or 4 minutes and then remove the brown stain by first rinsing the bleached film in water and placing it in a 1 per cent solution of sodium bisulphite. Wash for 3 or 4 minutes and then expose to a strong light until the white image turns purple. Redevelop in a non-staining developer such as Nepera solution 1 to 2, or Amidol without the use of bromide.

GROUNDGLASS. — To grind a mat glass, it is best to anchor it to a board or a table by cleats. The grinding can be done with another glass which is held in the hand or more conveniently by a handled suction cup such as is used to blow out clogged drains, or by a cork stopper stuck on the glass with cobbler's wax or with pitch. Select flat glasses, such as old negatives free from flaws and not bellied. Start the grinding with coarse emery or carborundum powder, made into a paste with water, between the two glasses and finish with finer materials, such as flour emery.

ETCHING GLASS. — To etch glass, dissolve by heat:

Sodium or potassium fluoride	20 gr.	4 g
Gelatin	20 gr.	4 g
Water	1 oz.	1000 cc

Coat on the glass and allow to set well and dry, then immerse in a 6 per cent solution of hydrochloric acid for 30 to 60 seconds, and dry without washing. The gelatin can be dissolved off with hot water and a fine mat surface is obtained.

Another method is as follows:

<i>Solution A</i>		
Sodium fluoride	60 gr.	60 g
Potassium sulphate	12 gr.	12 g
Water	1 oz.	500 cc
<i>Solution B</i>		
Zinc chloride	14 gr.	14 g
Hydrochloric acid	65 minims	65 cc
Water	1 oz.	500 cc

For fine lines, mix in equal quantities just before use and apply with a quill pen or fine brush. In about 30 minutes a good mat surface is obtained. A square or rectangle may be painted with the above solution, giving a mat surface upon which titles may easily be written with a soft lead pencil. The lines can be easily removed at any time with eraser or soap and water.

Hydrofluoric acid is inconvenient to use, for it must be kept in wax or gutta percha containers and is not a pleasant material to store because of its caustic fumes, but mixed with ammonium carbonate and water it makes an etching fluid, the proportions being varied to suit the case. White hydrofluoric acid for glass workers consists of about equal parts of 42° hydrofluoric acid and saturated solution of ammonium carbonate.

In most cases, the acid is liberated from one of its salts by other acids as needed. Local etching of designs can be done with wax coatings in which the design is cut. Obviously glass, porcelain, or enamel trays cannot be used. Wax coated wood, or hard rubber, or improvised lead trays are needed. Good ventilation is important. Keep the fingers out of the solution by using rubber gloves.

SILVERING GLASS AND MIRRORS.—Circular No. 389 of the Bureau of Standards gives this information. Cautions are given about the explosive nature of stock solutions under certain abnormal conditions, which should be noted.

In silvering, the silver is thrown down from ammoniacal silver nitrate by reducing agents. Unless proper care is taken, explosive compounds may be formed. The danger is greatest when potassium hydroxide is used, as in the older methods given by Brashear. Solutions of low concentration are quite harmless, but no residues should be allowed to dry. Vessels should be cleaned at once after use and the residues washed away. It is recommended that safety goggles be worn at all times.

Silver residues in large quantity have value and may be precipitated by acidifying with hydrochloric acid. Silvering solutions should be kept tightly corked to prevent evaporation and the formation of a dried deposit on the walls of the container.

C.P. chemicals must be used and pure water, preferably distilled, although rain water or specially pure tap water may sometimes be used. The merest trace of chlorine, even from the hands, may result in failure. If the silver nitrate solution has the slightest blue or pink color, it will not work. Alcohol denatured by Formula 3a of the Bureau of Internal Revenue is satisfactory, also Alcomb, but pure ethyl alcohol should be used if obtainable. Round-bottom flasks are best, as they can be cleaned with ease with nitric acid or bichromate cleaning solution. Metal vessels are not usable, but earthenware, porcelain, or enamelware can be used if kept for this purpose alone, or wooden vessels if well paraffined.

The silver solution is ruined by excess of ammonia, or by a slight shortage of ammonia which leaves undissolved silver oxide. The ammonia, C.P. concentrated, specific gravity 0.88 to 0.90, is added to the silver A solutions in small quantities and shaken. A precipitate will form and redissolve. This is repeated until the solution does not precipitate. Then solution B is added similarly, and when there is a permanent darkening, the balance is correct. If the solution clears in 1 or 2 hours, there is still excess of ammonia, a condition which will not work.

Brashear Formula.—The reducing solution is:

Distilled water	32 oz.	1000 cc
Tablet or granulated sugar	3 oz.	90 g
Nitric acid, sp. gr. 1.42	60 minims	4 cc

Tablet sugar is the purest form which can be obtained. Rock candy was formerly used. This solution may be prepared in large quantities, as it does not deteriorate and improves with age. Boiling can be omitted if it is prepared 1 or 2 weeks in advance. Alcohol, 175 cc, is used as a preservative if the stock solution is to be kept.

The silver solutions, which must be dissolved in the order given, are:

<i>Solution A</i>		
Distilled water	12 oz.	400 cc
Silver nitrate	300 gr.	20 g
Potassium hydroxide	150 gr.	10 g
<i>Solution B</i>		
Distilled water	1 oz.	30 cc
Silver nitrate	30 gr.	2 g

Wadsworth's older formula is:

<i>Solution A</i>		
Distilled water	10 oz.	300 cc
Silver nitrate	300 gr.	20 g
<i>Solution C</i>		
Distilled water	3½ oz.	100 cc
Potassium hydroxide	150 gr.	10 g
<i>Solution B</i>		
Distilled water	1 oz.	30 cc
Silver nitrate	30 gr.	2 g

Ammonia is added to solution A until the precipitate dissolves as usual. Solution C is then added, forming silver oxide, which is dissolved by more ammonia. Then solution B is added until a slight permanent darkening is seen. Each addition of ammonia is made as previously noted. The method given previously, dispenses with the first addition of ammonia, a considerable saving in time. Potassium hydroxide produces a precipitate which the ammonia afterwards dissolves. About 50 cc of ammonia (specific gravity 0.90) will be required. The above quantity of solution will silver about 125 square inches (800 sq. cm). The solutions are mixed immediately before use. Four parts of silver solution are used with 1 part of reducer.

Rochelle Salts Formula. — The reducer is:

Distilled water	32 oz.	1000 cc
Silver nitrate	30 gr.	2 g
Rochelle salts	25 gr.	1.7 g

The silver solution is heated to boiling for 5 minutes, and the Rochelle salts added. It should be kept in a brown glass bottle. The silver solution is:

<i>Solution A</i>		
Distilled water	3½ oz.	100 cc
Silver nitrate	150 gr.	10 g
<i>Solution B</i>		
Distilled water	1 oz.	30 cc
Silver nitrate	45 gr.	3 g

To solution A, sufficient concentrated ammonia is added to redissolve the precipitate first formed, after which solution B is added. With am-

monia of specific gravity 0.90, about 10 cc is needed. The solution is then diluted to 1000 cc and filtered. The silver solution and the reducer are mixed in equal volumes immediately before silvering, which should be done at room temperature, with the surface to be silvered a little warmer than the solution. This quantity will give a thick film on 60 square inches (400 sq. cm).

The Formaldehyde Formula. — The reducing solution is:

Distilled water	7 oz.	200 cc
Formaldehyde	676 minims	40 cc

The silver nitrate solution:

<i>Solution A</i>		
Distilled water	32 oz.	1000 cc
Silver nitrate	300 gr.	20 g
<i>Solution B</i>		
Distilled water	3½ oz.	100 cc
Silver nitrate	30 gr.	2 g

Add to solution A enough concentrated ammonia, specific gravity 0.90, to just redissolve the precipitate (about 10 cc). Then add solution B. For silvering, 5 parts of the nitrate solution are mixed with 1 part of reducer just before silvering. This goes well at 68° F. (20° C.) and takes from 90 seconds to 2 minutes. Higher temperatures give powdery deposits. Too little formaldehyde gives red-brown deposits with pinholes.

The Brashear and Rochelle salts methods are used regularly for silvering mirrors. Mirrors to be silvered on the front surface may be given thick films which adhere firmly to the glass, and permit frequent repolishing, by the Brashear method. This is the one generally used, but perfectly satisfactory ones may be obtained by the Rochelle salts method.

Shallow trays only a little larger than the mirror are used. Sometimes a paraffin paper rim can be tied around the edge of the mirror itself and cemented fast by a soldering iron. The glass is cleaned in the tray. Grease is removed by alcohol, ether, or other solvents, and then the glass is scrupulously cleaned with nitric acid. A swab of absorbent cotton on a stirring rod is used, avoiding scratches by the glass rod. A little distilled water is added to the nitric acid and considerable pressure is used. No spot should be allowed to dry. Rinse off the nitric acid with ordinary water, followed by distilled water, and the glass is then kept under distilled water in the tray until ready to silver.

Many advise a second cleaning in strong potassium hydroxide, followed by applications of French chalk and rinsing as above. The mirror surface emphasizes any lack of optical perfection of the glass surface, especially accidental scratches.

In commercial silvering a "secret of the trade" used by some people is saturated stannous chloride for cleansing. It is not of great value except that

it promotes a heavy deposit. Rubber gloves not only protect the hands from silver but prevent edge stains and contamination of the solutions.

Silvering with the glass upside down avoids sediment deposits, although it is otherwise less convenient. In this case the mirror must be supported above the bottom of the tray. The solutions are placed in two clean beakers and, with the Brashear method, the protecting water need not be poured off unless its volume greatly exceeds the silvering solution. With the others, the distilled water is replaced with more distilled water about 2 or 3° warmer than the solution proper.

Black sediments will form during silvering, and the trays should be rocked continuously. The silver deposit must be swabbed lightly all over its surface with loose cotton to keep the sediment from adhering. The mirror will tarnish if the solution is left on too long or if inspected out of the solution too long or too frequently. The laboratory should be free of sulphide fumes.

A heavier silver coat is made by successive fresh baths, with distilled water protection in the meanwhile. When a silvering is finished, it is rinsed in water and further rinsed with distilled water. If there is much "bloom," swab with cotton while rinsing.

The mirror is placed on edge to dry, drops on the bottom edge being removed with a blotter. On front silvering, the coating, when absolutely dry, is polished with circular strokes. The softest chamois skin obtainable is wrapped around a wad of cotton and a little of the finest optical rouge rubbed on the chamois.

The backs of the mirrors must be protected with two coats of shellac or covered with:

Gum dammar	77 gr.	10 g
Bitumen of Judea (Asphalt)	1 oz., 290 gr.	100 g
Red ochre	100 gr.	200 g
Benzole	16 oz.	1000 cc

For the protection of front-surfaced mirrors, a transparent nitro-cellulose lacquer is used, thinned with amyl acetate. Coatings which are too thin may show interference colors. Better results are obtained if the mirrors are left unvarnished. They may be protected from tarnishing by storing them in frames which have paper impregnated with lead acetate a short distance from the surface.

CELLULOID ADHESIVE.— Remove the emulsion from old films with boiling water. Cut the celluloid base into small strips and dissolve in amyl acetate, using such proportions as to form a thick syrup. This is a strong adhesive for many materials. Coat both surfaces of articles that are to be joined, and if the material is porous, like wood, allow the adhesive to dry and then apply another coating to each part before joining. Set aside under pressure until thoroughly dry.

CEMENTS. — For cementing glass to glass, or glass to metal, melt rubber and shellac in equal parts on a sand bath and apply to the warm glass or metal. Or glycerin and finely-powdered litharge may be worked into a thick paste, the broken edges painted with glycerin, the paste then applied, and the articles bound together with string and left for 1 or 2 days. Another good cement is zinc oxide worked into a stiff paste with a 15 per cent solution of zinc chloride. A very strong cement is made by mixing:

Sulphur flowers	72 parts
Pale resin	40 parts
Shellac	10 parts
Mastic	20 parts
Crude lac	20 parts
Barium sulphate	60 parts

Melt the gums by heat and add the sulphur, stir well and then add the baryta. This must be melted each time before use.

Diamond Cement. — Dissolve gelatin to saturation in glacial acetic acid. This must be melted on a water bath before use.

Damp-Proof Glue. — Cover some good glue with water and allow to soak for 12 hours, drain off the water, melt the glue by heat, and add one-quarter of its volume of linseed oil.

Marine Glue. — Dissolve India rubber shreds in benzol 1 part, shellac 2 parts; or ordinary bicycle tire cement may be used, one-quarter of its volume of shellac added, and melted by heat. The vapor of this is very inflammable.

Liquid Glue. — This should not be used for mounting photographs:

Fine glue	8 oz.	800 g
Water	10 oz.	1000 cc

Allow to soak for 24 hours, then melt by heat, and add:

Nitric acid (strong)	1½ oz.	175 cc
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RETOUCHING consists of adding pigment locally (usually from a pencil) to the surface of a negative to make it print lighter, or in removing by mechanical means part of the silver deposit to make it print darker. It was formerly a standard part of the procedure in making portrait negatives, being used to correct technical faults, tone down or subdue wrinkles and freckles, eliminate facial defects, remove superfluous hair, lighten shadows, straighten crooked noses, and for a host of other purposes. With the more common use of color-corrected emulsions, lenses giving soft definition, and better controlled lighting, the need for extensive retouching has largely been obviated. The general use of smaller negatives which usually have to be enlarged, has also made the use of retouching less desirable as marks upon a negative which are not noticeable on a contact print show up unpleasantly when enlarged. Still, there are many occasions when slight retouching upon a negative will greatly

improve the result, especially in the matter of removing mechanical defects like scratches and pinholes. Retouching, in order to be acceptable, must be indistinguishable on a print at ordinary viewing distances. Retouching is not tolerated upon scientific, historical, or documentary work.

Pencils will not mark upon the gelatin surface of negatives unless it has been prepared with a special varnish called *retouching medium* or *dope*. This can be bought very inexpensively from photographic dealers. These dopes are mixed according to quite elaborate formulas, as:

RETOUCHING MEDIUM

Pale gum resin	200 gr.	22.5 g
Gum dammar	90 gr.	10 g
Gum mastic	20 gr.	2.25 g
Oil of juniper	1 dram	6 cc
Oil of turpentine	2 oz.	100 cc

A quite satisfactory medium can be made as follows:

Gum dammar	1 part
Turpentine	5 parts
Benzene	5 parts

Add 4 or 5 drops of oil of lavender or castor oil to each 5 ounces (150 cc) of the mixture.

The retouching medium is applied with a soft rag to the part of the negative that is to be worked on, and immediately wiped off with a clean cloth so that only a trace remains.

Retouching is done with pencils of various degrees of hardness depending upon the density of the deposit required, but it is well to confine the work as much as possible to the use of hard pencils, depending upon repeated applications to get the required density. It is more difficult to get a smooth effect with soft pencils, the most useful ones ranging from H to 4H. These pencils must be kept to a very fine point to insure the delicacy of the work required. This can be accomplished only by trimming the lead to a long bevel and then making the fine point by rubbing upon very smooth sandpaper.

The work must be done under a magnifying glass. A reading glass suspended over the work is very convenient. Single eyeglasses may be used for occasional work, but if much work is to be done, binocular lenses or the reading glass should be used to lessen eye strain.

Fine work can be done with overlapping lines if a very hard pencil is used, but larger areas must be filled in with a very fine pattern of lines consisting of whirligigs, commas, or stipples. Every worker develops his own technique in this respect. The novice should practice first upon a discarded negative, pulling occasional proofs enlarged as much as his final result is to be, to see the effect of his work. The work is not difficult, but it requires painstaking care, and some amount of practice is required to get the knack.

If the work is not satisfactory it can all be removed, including the medium, with a rag soaked in turpentine or carbon tetrachloride (Carbona).

Pinholes clear through the emulsion are difficult to fill up with pencil unless the surrounding area is very light. They are usually filled by using black water color, or India ink thickened with a little mucilage, and applying it with a twirling motion with a very fine pointed brush. It is almost hopeless to try to dilute the color so that it will exactly match the surrounding area of the negative. The general practice is to make the spotting a little darker than needed so that it will print a little lighter than the surrounding area, and this defect is easily spotted out on the print.

Silver is removed locally from a negative so that it will print lighter, by the use of etching tools. These range from needle shape to larger ones with beveled edges with which the silver may be pared away in layers. This requires much more skillful work and longer practice than it does to apply pigment to a negative. The first, and absolutely essential, requirement is that the tools be kept as sharp as a razor — literally. There should always be at hand a small, fine-grained whetstone for frequent sharpening of the tools and a piece of smooth leather upon which they are stropped for the finishing touches. If the tool is dull it will tear the film instead of making the clean cut that is necessary for acceptable work. During the course of the work the tools are kept in condition by frequently giving them a few gentle rubs on the stone, followed by stropping on the leather.

An expert, after long practice, can do wonders on a negative with an etching knife, but the beginner must practice long and assiduously upon discarded negatives before hoping to attain this proficiency.

In general it is desirable to confine the etching to the upper layers of the emulsion without penetrating clear through to the base. An exception is made in the case of very small, dark areas which can be lightened, even by the novice, by stippling clear through the emulsion with the needle point.

A suitable retouching stand is an almost indispensable convenience for this work. As commercially supplied, this consists of a framework with a canopy for shielding the work from side light. The negative is supported upon a groundglass plate and lighted by light reflected by a mirror beneath. To protect the eyes, the groundglass should be covered with a mask with an opening just large enough to cover the area of the negative that is being worked on. The mirror can often to advantage be replaced by, or covered with, a sheet of white card to give a softer light.

REMOVING THE GELATIN BACKING FROM FILMS. — If the backs of films are scratched or stained, they may be completely renovated by removing the gelatin from the back. Squeegee the negative, emulsion side down, on to a sheet of Kodaloid which has been coated with rubber cement diluted with enough benzene to make it flow freely and to which 5 per cent amyl acetate has been added. Then immerse the film with the Kodaloid sheet to which it

adheres, in 5 per cent sulphuric acid at a temperature of 100° to 110° F. (38° to 43° C.). This temperature must be maintained for 15 minutes or so, when the gelatin will be dissolved. After washing and drying, the Kodaloid is stripped off.

RENOVATING FOCUSING SCALES.—A mixture of lampblack with tallow is very good for emphasizing the lines on focusing scales. Melt the tallow in a small container and stir in ivory black or lampblack to make a thick paste. This sets stiff and keeps very well. Rub it over the engraved marks with a spatula or a knife blade. Rub it off with a rag. The mixture will stay in the marks. A similar white filling may be made by using whiting or plaster of Paris instead of lampblack.

RENOVATING CLOTH BELLOWS.—These may be revived by a mixture of:

Alcohol	16 oz.	64 cc
Shellac	4 oz.	16 g
Oxalic acid	$\frac{1}{2}$ oz.	1 g
Linseed oil	3 oz.	12 cc

The first three chemicals are completely mixed by shaking before the linseed oil is added. Apply with absorbent cotton and remove the surplus with a cloth.

GROUNDGLASS SUBSTITUTE.—

Water	200 parts
Rice starch	20 parts
Waterglass	100 parts

The waterglass is the ordinary commercial solution of sodium silicate of 1.3 specific gravity. Mix the above by first rubbing the starch up with the water and then adding the silicate. Level a sheet of glass and pour enough of the solution on to cover it, allow to dry, then coat with celluloid varnish.

CARE OF TRAYS.—Fragile trays need protection and glass trays may not stand hot solutions. Clean trays just after use, and rinse them to remove dust, just before use. Trays of hard rubber may be deformed by heat, especially if stored on edge, but they may be softened by immersion in hot water and then bent back into shape. Steel enamel trays are unbreakable but they should not be stacked unless nested between newspapers, as the glaze is brittle and may crack. Cracked or chipped trays bare the iron base, and may cause developer stains or blue stains in redeveloping or bleaching processes. Trays are preferably stored on edge in wooden racks.

REPAIR OF TRAYS.—Papier maché trays are light and so are much used in engraving plants, where large plates are used. For these, marine glue is good. Bakelite cement makes an excellent permanent repair for the corners and junctions, which are often abraded by the plates sliding around.

Celluloid trays may be repaired with celluloid dissolved in amyl acetate or ordinary film cement.

Vulcanite (hard rubber) trays can be mended by running a red-hot wire along the fractures and bringing them together quickly and firmly. Marine glue or elastic glue may also be used, or India rubber solutions, or cements.

Earthenware dishes may be cemented with a mixture of oxide of zinc with deliquescent zinc chloride. The oxide is a white powder. The zinc chloride is added to about its own bulk of water, and the edges are moistened with it. Then the oxide is added to the chloride solution to make a thick cream, with which the break is coated. The parts must be brought together quickly and firmly. Solid shellac may also be used. The edges of the crack are heated and rubbed with the shellac. They are again heated and pressed into contact. Such dishes cannot be used for hot liquids.

To cement glass dishes, Canada balsam is heated in an oven in a pan. The layer of balsam will become solid and brittle and is then soluble in either chloroform or benzol. Trays thus repaired are suitable only for cold liquids.

In some cases, celluloid varnishes can be used over cracks on wooden, porcelain, and enamel trays. Such coatings do not resist strong caustic alkalies nor lacquer solvents such as amyl acetate.

TO FIND THE CAPACITY OF A TANK. — This may be estimated from the volume of space inside and, conversely, the measurement may be found which will contain a definite number of ounces or gallons, etc. If the inside dimensions of a container are, say, 24 by 12 by 6 inches, it contains 1728 cubic inches. A gallon of water occupies 231 cubic inches, so a tank of this size would hold $1728 \div 231$, or 7.48 gallons. The U. S. gallon contains 128 fluid ounces and so we can easily ascertain that the contents of the tank as specified would be 7 gallons and 61.44 ounces.

The weight of a gallon of water at normal temperature is 8.313 pounds, but in finding the weight of the developing solution in a tank the total weight of the chemicals must be added to the weight of the water.

If a tank is cylindrical, the inside diameter squared, multiplied by 0.7854, gives the area of the circle, and the area multiplied by the height of the tank gives the cubic contents in inches. This cubic content divided by 231 gives the number of gallons that the tank will hold.

PHOTOGRAPHIC MOUNTS. — Mounts larger than can be handled by available shear cutters, may be cut by a knife held against a straightedge of brass or steel which may have a strip of surgeon's tape stuck along its underside to keep it from slipping. Any sharp, thin blade will do the cutting. Razor blades are often used, especially those in special holders, but if the mount is very heavy a stouter blade is desirable as the thin blades are likely to buckle if much pressure is used. A shoemaker's knife with a large handle that can be grasped easily is very convenient. With any blade larger than a razor blade a whetstone and a leather strop should be frequently employed to keep the knife sharp, as a dull knife makes ragged edges. A piece of plate glass is the best support for the mount while it is being cut. The hard,

smooth surface of the glass dulls the knife surprisingly little when it cuts through. Wood, or heavy cardboard, can be used for the supporting surface, but they must be frequently renewed as they become scored by the knife and then give rough edges.

Beveled edges for openings in mounts are made by having a beveled edge on the straightedge as a guide for the angle at which the knife is held.

Die-sunk effects are made by ruling a rectangle of the desired size correctly spaced on the mount. The mount is supported on a sheet of glass with the illumination coming through from beneath. Such a support can be improvised by supporting the glass on each end by a pile of books and placing an electric light underneath it. A strip of celluloid with a straight edge is slipped under the mount and the edge of the celluloid registered with one of the ruled lines of the rectangle. A professional embossing tool, which consists of a small steel ball mounted in a handle so that it revolves freely, is rubbed on the front surface of the mount, pressing it against the edge of the celluloid beneath, using force enough to crease the mount. The handle of a tablespoon, or any other smooth, rounded implement, can be used instead of the embossing tool. The celluloid is successively moved and registered with the other sides of the rectangle, which are embossed in turn.

Prints should not be mounted with paste because when the moisture dries out of it the mount will be warped. If paste must be used, this tendency can be minimized by pasting a sheet of the same kind of paper with the same mountant on the back of the mount so that in drying the pull of the two sheets will tend to offset each other, but the mount will never stay even approximately flat. Prints may be mounted by spots of glue applied along the edges, but this is good for only a limited time because the print will absorb more moisture from the air than the mount will, and so the print will eventually be wrinkled. Prints are sometimes mounted with adhesive on the top edge of the print only, allowing the print to hang free on the mount, but this practice cannot be recommended as the prints are easily torn and creased in handling, and unless under glass they have a tendency to curl with changing atmospheric conditions. A better job is done by mounting the whole surface of the print flat with rubber cement. Apply a coating of the cement to both the back of the print and to the mount. Allow these coatings to dry and fill up the pores of the paper. Then apply a second coat to both the print and the paper, and when these coatings have dried enough to become tacky, rub them firmly into contact and allow to dry completely under pressure. Prints so mounted will eventually become detached, but the process is good for three or more years, depending upon the humidity of the atmosphere where they are kept. They can be detached at any time by a strong enough pull.

Prints may also be mounted by spreading a strong solution of shellac in denatured alcohol on both print and mount, pressing the two surfaces together and leaving under considerable pressure until dry.

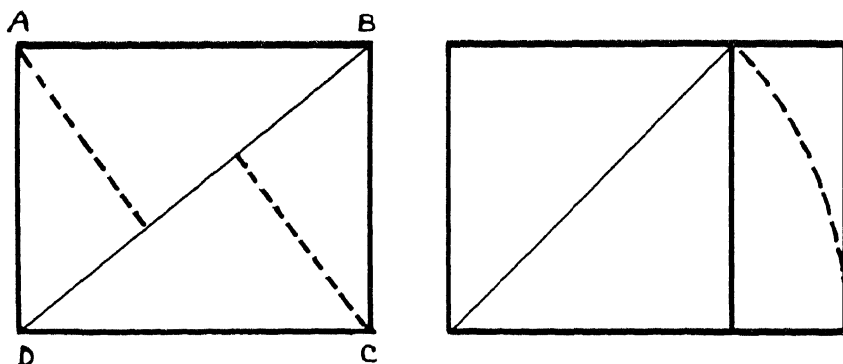
Although no method of mounting will insure prints upon light-weight mounts remaining absolutely flat under the changes of temperature and moisture content of the air which they must undergo either in the home or on the walls of exhibitions, by far the most satisfactory mountant is dry mounting tissue. This consists of sheets of very thin paper coated on both sides with shellac. The tissue is lightly tacked to the back of the print by the application of a hot iron and then trimmed to size so that none protrudes. Tacking irons are commercially available, but an electric soldering iron makes a good substitute, or a screwdriver blade may be heated in a flame. The print is placed in position on the mount with the tissue in contact with the mount, and preferably tacked to the mount so that it will not move during subsequent operations. Mounting is completed by applying pressure with sufficient heat to melt the shellac. Dry mounting presses that supply the correct amount of heat and pressure are the most convenient means of mounting, but good work can be done with a domestic electric iron. The iron should be just hot enough so that it sizzles when tapped with a wet finger. If too hot, the tissue will stick to the mount and not to the print. If too cold it will stick to the print and not to the mount. Mounted prints may be removed from the mount by applying slightly more heat than was necessary to make the tissue adhere, and then quickly stripping the print from the mount. The dry mounting tissue provides an impermeable coating between the print and the mount so that no impurities in the mount can affect the print.

Cleaning Mounts. — Slightly soiled mounts can be cleaned with Artgum, but for obstinate cases powdered pumice applied with a tuft of cotton or a flannel rag may be needed.

MOUNTING ON CLOTH. — Prints are often mounted on cloth for durability and flexibility, as for use by salesmen. The cloth is furnished commercially with an adhesive backing. For glossy prints, the print is first placed on the ferrotype plate, and then a piece of cloth slightly larger than the print is moistened and laid over it and the two are squeegeed on to the plate in contact and allowed to dry that way, when they may be stripped from the plate together and the cloth trimmed to size. For mat or semi-mat prints, the wet print is laid on a sheet of glass, the cloth is moistened and laid over it and the two squeegeed together, then stripped from the glass and dried as usual. For mounting prints on both sides of the cloth, cloth with adhesive on both sides is provided. One of the wet prints is placed face down on a sheet of glass illuminated from below. The moistened cloth is placed over the first print, and then by means of the light the second print is registered, face up, over the first print with the cloth between. They are squeegeed into close contact with the cloth and then removed from the glass and dried on stretchers if the prints are mat surfaced. Glossy prints after being stuck to the cloth, are squeegeed to a ferrotype plate on each side. This requires considerable pressure, and a wringer is a great help.

DYNAMIC SYMMETRY, as explained by Jay Hambidge, states certain laws of arrangement, proportion, and design, derived from analysis of early Greek art. Two of these principles, as shown in the accompanying drawing, are often used by pictorial photographers.

In the first figure, a diagonal, DB , of the rectangle $ABCD$ has been drawn. From this diagonal perpendiculars have been erected to the corners A and C . At either of the points where these perpendiculars meet, the diagonal is considered a favorable place for locating the center of interest in the rectangle. The diagonal AC might also be drawn and from it perpendiculars erected to the corners B and D which would similarly indicate two more favorable points for the location of the center of interest. The choice between the four is determined by the nature and shape of the subject matter.



DYNAMIC SYMMETRY. On the left, points of interest. On the right, the Root Two rectangle

The second figure shows a method of securing pleasing proportions for a rectangle. Using the diagonal FB of the square $ABEF$ as a radius, an arc is drawn intersecting the prolongation of the side FE of the square at D , giving the rectangle $ACDF$. Using FC as a radius, another rectangle of pleasing proportions could be similarly constructed from the first.

DRAWING OVALS (more correctly *ellipses*). — It is sometimes necessary to cut prints or mounts to an oval shape. Brass cut-out plates are available for this purpose, but they are supplied in stock sizes only and it is often necessary to have a special oval drawn to fit the exact dimensions of a certain print, or to avoid carrying a large stock of these plates unless they are constantly used. The accompanying diagram shows how an oval may be drawn to any dimensions.

Lay off the lines AB and CD which bisect and are at right angles to each other. AB represents the height of the desired oval, and CD its width. With D as a center and a radius equal to one-half AB , describe an arc intersecting

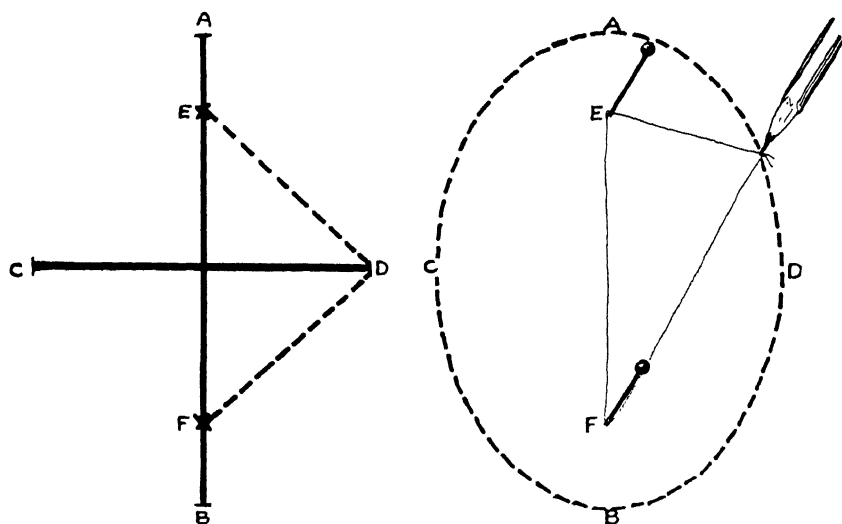


Diagram for Drawing an Ellipse

AB at *E* and *F*. Insert pins at *E* and *F* and tie around them a loop of thread equal to the distance *EDFE*. If a pencil point is inserted in the loop, holding it taut away from the pins, as it is moved it will describe the oval *ADBCA*.

THE GOLDEN SECTION (*sectio aurea*), or the Golden Divide as it was variously called, indicates the point in a line at which it must be divided so that the two parts bear the most pleasing relationships to each other, according to a theory that has been used since classical times.

A

B

C

THE GOLDEN SECTION

The proportion is $AB:AC = BC:AB$. The longer section has the same proportion to the whole line as the shorter section has to the longer. The problem is solved nearly enough for most purposes by letting $AB = 1$, and $AC = 1.62$.

RESTORING TARNISHED DAGUERREOTYPES. — If daguerreotypes are unduly exposed to strong light the silver surface becomes oxidized and the image partially obscured by a brown or blue deposit. With great care this deposit can be removed but there is always some risk that the daguerreotype may be spoiled in the process of restoration. This work should never be undertaken without first informing the owner that there is a possibility that it may not be successful. It is a wise precaution to make a copy of the daguerreotype before attempting any work upon it (see page 284).

The plate must first be unbound, taking great care that the fingers never touch the surface of the daguerreotype, and then placed face upwards in distilled water in a clean porcelain or glass dish, and well rinsed by constant rocking. If the water seems to be repelled from the surface as if it were greasy, flow a little methylated spirit over it. The water or spirit is then poured off and the plate covered with a solution of potassium cyanide, 10 grains to an ounce of distilled water. Only a small quantity of this solution should be applied at a time, frequently renewing it until the deposits are removed. The plate is then rinsed in several changes of distilled water while holding it by a bottom corner with a pair of pliers, and is then dried quickly by holding it over a flame. Uneven drying is likely to cause stains.

LINE DRAWINGS FROM PRINTS. — Waterproof drawing ink should be used in drawing over any desired part of the print; then immerse it in:

Iodine	3.84 gr.	0.5 g
Potassium cyanide	0.25 gr.	0.03 g
Water	16 oz.	1000 cc

Rub the cyanide up with the iodine, add first a very little water, and then make up to bulk. Or the following may be used:

Thiocarbamide	119 gr.	15.5 g
Nitric acid	119 minims	15.5 cc
Water	16 oz.	1000 cc

Or:

Water	16 oz.	1000 cc
Potassium bichromate	62 gr.	8 g
Sulphuric acid	90 minims	12 cc

Then wash well.

An ink suitable for this process is made from:

Hot water	10 oz.	100 cc
Borax	$\frac{1}{2}$ oz.	5 g
Shellac	$\frac{1}{4}$ oz.	2.5 g

Add the shellac to the borax in water, and boil until the shellac dissolves. Cool and filter it, then rub it up with India ink.

GLASS STOPPERS often stick in the neck of bottles. In hot weather the bottle expands, letting the stopper drop lower into the neck. With colder weather the neck contracts, gripping the stopper. A preventive is to smear the stopper with a trace of vaseline. The stopper can often be started by heating the neck of the bottle with a candle or the flame of a match, taking care not to apply the heat suddenly enough to break the bottle.

CHAPTER XXIV

WEIGHTS AND MEASURES

WEIGHTS AND MEASURES. — Formulas in this book are given in both U. S. and metric weights and measures. The metric weights and measures are not the exact equivalents of those in the other systems, but the ratio of the ingredients in each column is the same. Readers must therefore rigidly adhere to one or the other system.

These formulas have been gathered from many sources, and appear as they were presented in the original, which accounts for some of the lack of uniformity in the total volume of solution for which the formulas are written. In other cases the difference in volume indicates the probable amount that would be used in ordinary procedure.

The dry form (desiccated or anhydrous) of sodium carbonate and sodium sulphite are always assumed in the formulas in this book, unless another form is specified. When substituting other forms for the desiccated sodas, use 3 parts of crystalline, or $1\frac{1}{2}$ parts of monohydrated carbonate for 1 part of desiccated; and 2 parts of crystalline sulphite for 1 of desiccated.

In making photographic solutions, it is the usual custom to dissolve the dry ingredient in some of the solvent, and then add enough more of the solvent to make up to the given bulk, and this procedure is specified in many of the formulas. The same procedure may be followed in most of the other formulas without detriment to the final result, as a slight difference in the amount of dilution is negligible in most photographic processes. For the exact reproduction of results, however, the same system of compounding solutions should be adhered to in every case where a formula is used.

Chemicals are universally sold by avoirdupois weight and formulas are now generally given in that system. The avoirdupois ounce contains $437\frac{1}{2}$ grains and the pound contains 7000 grains, the grain being the same as in apothecary or troy weights. The apothecary or troy pound is fixed at $5760/7000$ of the standard avoirdupois pound, which was first the weight of 27.7015 cubic inches of distilled water weighed in air at 39.83° F. (4° C.), with the barometer at 30 inches, and is standardized now as being equal to 453.5924 grams of the international unit of the metric system.

Photographic formulas are almost invariably given in the avoirdupois system, in which the ounce, dry measure, contains 437.5 grains; the liquid ounce

contains 480 minims. Occasionally the word "drachm" or "dram" is used, and this usually refers to the apothecaries' system of 60 grains or 60 minims. The avoirdupois "dram" contains 27.34375 grains. The use of this term, as well as "pint" and "gallon," should be avoided as far as possible, as the U. S. pint contains 16 fluid ounces, the U. S. gallon 128 fluid ounces, and the British pint is 20 fluid ounces, the British gallon 160 fluid ounces.

AVOIRDUPOIS WEIGHT

1 dram	=	27.343 grains
16 drams	=	1 ounce
16 ounces	=	1 pound

OUNCES AND EQUIVALENTS IN GRAINS

Ounces	Grains	Ounces	Grains	Ounces	Grains	Ounces	Grains
$\frac{1}{8}$	54.7	1	437.5	$2\frac{3}{4}$	1203	$4\frac{1}{2}$	1969
$\frac{1}{4}$	109	$1\frac{1}{4}$	546	3	1312	$4\frac{3}{4}$	2078
$\frac{3}{8}$	164	$1\frac{1}{2}$	656	$3\frac{1}{4}$	1421	$5\frac{1}{4}$	2296
$\frac{1}{2}$	219	$1\frac{3}{4}$	765	$3\frac{1}{2}$	1531	$5\frac{1}{2}$	2406
$\frac{5}{8}$	273.5	2	875	$3\frac{3}{4}$	1640	6	2625
$\frac{3}{4}$	328	$2\frac{1}{4}$	984	4	1750	$6\frac{1}{4}$	2734
$\frac{7}{8}$	382.9	$2\frac{1}{2}$	1094	$4\frac{1}{2}$	1859	$6\frac{1}{2}$	2844

APOTHECARIES WEIGHT

20 grains	=	1 scruple
3 scruples	=	1 dram
8 drams	=	1 ounce
16 ounces	=	1 pound

$\frac{1}{2}$ scruple	=	10 grains	1 dram	=	60 grains
1 scruple	=	20 grains	2 drams	=	120 grains
2 scruples	=	40 grains	3 drams	=	180 grains

Old formulas were often given in this system as the scruple and dram weights were very convenient as substitutes for small amounts in grains in an avoirdupois formula. The grains are the same in both systems.

FLUID MEASURE

60 minims	=	1 dram
8 drams	=	1 ounce = 480 minims
4 ounces	=	1 gill
16 ounces	=	1 pint
32 ounces	=	1 quart
128 ounces	=	1 gallon

Note that the above are U. S. measures and that the British or Imperial pint contains 20 ounces, an Imperial quart 40 ounces, and an Imperial gallon 160 ounces. Due allowance must always be made when handling these quantities in English formulas if the terms pint, quart, and gallon are used instead of the quantity being expressed in ounces.

INTERRELATION OF SYSTEMS. — In Circular No. 47, U. S. Bureau of Standards, may be found rather elaborate tables showing the interrelation of the units of different systems including metric. Copies of this circular may be obtained from the U. S. Government Printing Office, Washington, D. C., price 15 cents each. Metric values have long been legalized in this country and all our customary weights and measures are dependent by law upon the standards of the International Bureau of Weights and Measures.

Units of length and area are derived from the international meter at the legal equivalent (law of July 28, 1866), 1 meter = 39.37 inches. In 1893 the yard was derived from the meter at the value, $3600 \div 3937$. Similarly weights are referred to standard kilograms (Executive order, 1893).

Units of capacity are based on the equivalent of 1 liter = 1.000027 cubic decimeters. The U. S. gallon contains 231 cubic inches and must not be confused with the British gallon.

Weights are based on the international kilogram in which 1 pound or 7000 grains = 453.5924277 grams. A troy pound is $5760 \div 7000$ avoirdupois pounds.

A change in temperature affects the standards of length, capacity, etc., although the units themselves may be fixed ones. A definite temperature must be established if accurate comparisons are to be made, on account of the shrinkage or expansion in length or volume. The capacity standards of the United States are fixed at a temperature of 4°C ., at which water reaches its maximum density. If extreme accuracy is needed at other temperatures, the exact equivalents can be found by means of tables.

In photography, the temperature affects the volume of liquids so that hydrometers are notoriously inaccurate when tested at temperatures other than that for which the readings are given, which are not often stated. The practice of buying liquids by weight instead of volume is the only logical one. Acids are sold in this way, by weight, and a heavy acid, like sulphuric acid which has a specific gravity of 1.8, takes up less space. While most photographic formulas do not need to be compounded with extreme accuracy, it is just as well to work with the solutions at an average room temperature of about 68°F . (20°C .).

THE METRIC SYSTEM. — The prefixes used in metric terminology are:

Deci	= one-tenth	Deka	= 10 times
Centi	= one-hundredth	Hecto	= 100 times
Milli	= one-thousandth	Kilo	= 1000 times

The unit of length is the meter, and the unit of weight (mass) is the gram. A decimeter is one-tenth of a meter, a decigram is one-tenth of a gram. A centimeter is one-hundredth of a meter and a centigram is one-hundredth of a gram. A dekagram is 10 grams, a hectogram is 100 grams, and a kilogram 1000 grams. Similarly, a dekameter is 10 meters, a hectometer is 100 meters, and a kilometer is 1000 meters.

In photography only a few of these prefixes are ever used, the general practice being to write the multiples in full, and the subdivisions decimally, as: 100 g, 0.1 g, etc. Plate and film sizes are often expressed in centimeters or in millimeters and the focal length of lenses may be stated either in centimeters or in millimeters. In making up solutions, while the liter is the unit of capacity, the cubic centimeter and its multiples are better adapted for that purpose.

USEFUL EQUIVALENTS

LINEAR

1 inch	=	25.4 millimeters
1 foot	=	0.3048 meter
1 yard	=	0.9144 meter
1 mile	=	1.6093 kilometers
1 millimeter	=	0.03937 inch
millimeters \div 25.4	=	inches
1 centimeter	=	0.3937 inch
1 meter	=	39.3704 inches
1 meter	=	3.2808 feet
1 meter	=	1.0936 yards
1 kilometer	=	0.6213 mile
kilometers \div 1.6093	=	miles
1 kilometer	=	3280.833 feet

VOLUME

1 minim (water)	=	0.06161 cubic centimeter
1 fluid dram	=	3.6966 cubic centimeters
1 fluid ounce	=	29.5729 cubic centimeters
1 ounce apothecary (water)	=	31.1035 cubic centimeters
1 pint (16 ounces)	=	0.4732 liter
1 quart (32 ounces)	=	0.9463 liter
1 gallon (128 ounces)	=	3.7853 liters
1 cubic inch	=	16.3871 cubic centimeters
1 cubic foot	=	0.0283 cubic meter
1 cubic yard	=	0.765 cubic meter
1 cubic centimeter	=	16.23 minims (water)
1 cubic centimeter	=	0.2705 fluid dram
1 cubic centimeter	=	0.0338 fluid ounce
1 liter	=	1.0567 quarts
1 liter	=	0.26418 gallon
1 liter	=	33.8147 fluid ounces
liters \div 3.7853	=	gallons (231 cubic inches)
1 cubic centimeter	=	0.061 cubic inch
cubic centimeters \div 16.387	=	cubic inches
cubic centimeters \div 3.6966	=	fluid drams
cubic centimeters \div 29.5729	=	fluid ounces
1 cubic meter	=	35.3357 cubic feet
1 cubic meter	=	1.3079 cubic yards
1 cubic meter	=	264.15 gallons
1 liter	=	61.0232 cubic inches
liters \div 3.7853	=	gallons
liters \div 28.3170	=	cubic feet

WEIGHT

1 grain	=	64.7989 milligrams
1 ounce avoirdupois	=	28.3495 grams
1 ounce troy	=	31.1035 grams
1 pound avoirdupois	=	0.4536 kilogram
1 pound troy	=	0.3732 kilogram
1 pound avoirdupois	=	453.5924 grams
1 milligram	=	0.01543 grain
1 gram	=	15.4323 grains
1 kilogram	=	2.2046 pounds avoirdupois
1 kilogram	=	2.6792 pounds troy
1 kilogram	=	35.2739 ounces avoirdupois
1 kilogram	=	35.1507 ounces troy

MISCELLANEOUS

1 gallon (United States)	=	231 cubic inches
1 gallon (United States)	=	8.313 pounds avoirdupois
1 gallon (United States)	=	58418.144 grains
1 pound avoirdupois (water)	=	0.1203 gallon
1 fluid ounce (water)	=	456.392 grains
1 fluid ounce (water)	=	1.0391 ounces avoirdupois
1 ounce avoirdupois (water)	=	0.9623 fluid ounce
1 cubic inch (water)	=	252.892 grains
1 liter (water)	=	1 kilogram
1 liter of water \times specific gravity of liquid	=	weight in grams of liquid
1 United States gallon	=	0.83267 Imperial gallon
1 Imperial gallon	=	1.201 United States gallons

TABLE TO CONVERT GRAMS PER LITER TO GRAINS PER 16 OUNC

<i>Grams per liter</i>	<i>Grains per 16 ounces</i>	<i>Grams per liter</i>	<i>Grains per 16 ounces</i>
1	7.68	10.5	80.64
1.5	11.52	11	84.48
2	15.36	11.5	88.32
2.5	19.2	12	92.16
3	23.04	12.5	96.0
3.5	26.88	13	99.84
4	30.72	13.5	103.68
4.5	34.56	14	107.52
5	38.4	14.5	111.36
5.5	42.24	15	115.2
6	46.08	15.5	119.04
6.5	49.92	16	122.88
7	53.76	16.5	126.72
7.5	57.6	17	130.56
8	61.44	17.5	134.4
8.5	65.28	18	138.24
9	69.12	18.5	142.08
9.5	72.96	19	145.92
10	76.8	19.5	149.76
		20	153.6

For larger numbers, multiply or add. Thus, for 25 grams per liter, multiply the value of 10 grams per liter by $2\frac{1}{2}$, or add the values for 10 and 15. For

5.6 grams per liter, take the value for 5 and add one-tenth of the value for 6. For larger numbers of grams the following values are given:

<i>Grams per liter</i>	<i>Grains per 16 ounces</i>	<i>Grams per liter</i>	<i>Grains per 16 ounces</i>
75	1 oz., 139 gr.	300	5 oz., 116 gr.
100	1 oz., 330 gr.	325	5 oz., 308 gr.
125	2 oz., 85 gr.	350	6 oz., 63 gr.
150	2 oz., 277 gr.	375	6 oz., 255 gr.
175	3 oz., 32 gr.	400	7 oz., 10 gr.
200	3 oz., 224 gr.	425	7 oz., 201 gr.
225	3 oz., 416 gr.	450	7 oz., 393 gr.
250	4 oz., 170 gr.	475	8 oz., 148 gr.
275	4 oz., 362 gr.	500	8 oz., 340 gr.

TABLE TO FIND THE NUMBER OF GRAMS PER LITER
(Divide the number of grains per ounce by the factors given)

<i>Ounces</i>	<i>Grams per liter</i>	<i>Ounces</i>	<i>Grams per liter</i>
1	0.48	10.5	5.04
1.5	0.72	11	5.28
2	0.96	11.5	5.52
2.5	1.2	12	5.76
3	1.44	12.5	6.0
3.5	1.68	13	6.24
4	1.92	13.5	6.48
4.5	2.16	14	6.72
5	2.4	14.5	6.96
5.5	2.64	15	7.2
6	2.88	15.5	7.44
6.5	3.12	16	7.68
7	3.36	16.5	7.92
7.5	3.6	17	8.16
8	3.84	17.5	8.4
8.5	4.08	18	8.64
9	4.32	18.5	8.88
9.5	4.56	19	9.12
10	4.8	19.5	9.36
		20	9.6

IN CONVERTING METRIC TO ENGLISH OR AMERICAN FORMULAS, it is not necessary to find the exact equivalents as long as the strength of the solution is the same. The following formula, for example:

Gold chloride 1 g
Ammonium sulphocyanide 15 g
Water 1000 cc

may be set down as:

Gold chloride 1 gr.
Ammonium sulphocyanide 15 gr.
Water 1000 minims

and a volume of 16 ounces may be obtained by using the factor of 7.68 as given in the table, and other values such as 32 ounces, 8 ounces, or 4 ounces can be obtained by simply multiplying or dividing the totals thus obtained. Similarly, for formulas containing a total volume of 10 ounces or 20 ounces, factors of 4.8 and 9.6 will give the required values, or a 20 ounce volume can be obtained by taking $1\frac{1}{4}$ times the 16 ounce values.

APPROXIMATE RULE TO CONVERT ENGLISH WEIGHTS AND MEASURES INTO METRIC. —

1. Call the new volume of solvent 1000 cc.
2. If any of the ingredients run to ounces, take their ratio to the solvent, and write down the same ratio to 1000 in grams.
3. Divide each grain item by half the number of ounces, and write the result down in grams.

TABLE OF METRIC AND ENGLISH EQUIVALENTS. —

LENGTHS

<i>Inches</i>	<i>Centimeters</i>
0.3937	= 1
0.7874	= 2
1.1811	= 3
1.5748	= 4
1.9685	= 5
2.3622	= 6
2.7559	= 7
3.1496	= 8
3.5433	= 9

<i>Inches</i>	<i>Centimeters</i>
1	= 2.54
2	= 5.08
3	= 7.62
4	= 10.16
5	= 12.70
6	= 15.24
7	= 17.78
8	= 20.32
9	= 22.86

AREAS

<i>Square Inches</i>	<i>Square Centimeters</i>
0.155	= 1
0.310	= 2
0.465	= 3
0.620	= 4
0.775	= 5
0.930	= 6
1.085	= 7
1.240	= 8
1.395	= 9

<i>Square Inches</i>	<i>Square Centimeters</i>
1	= 6.452
2	= 12.903
3	= 19.355
4	= 25.807
5	= 32.258
6	= 38.710
7	= 45.161
8	= 51.613
9	= 58.065

MASSES

<i>Grains</i>	<i>Grams</i>
1	= 0.0648
2	= 0.1296
3	= 0.1944
4	= 0.2592
5	= 0.3240
6	= 0.3888
7	= 0.4536
8	= 0.5184
9	= 0.5832

<i>Grains</i>	<i>Grams</i>
15.4324	= 1
30.8647	= 2
46.2971	= 3
61.7294	= 4
77.1618	= 5
92.5941	= 6
108.0265	= 7
123.4589	= 8
138.8912	= 9

LIQUIDS

<i>Cubic Centimeters</i>	<i>Minims</i>
1 =	16.23
2 =	32.46
3 =	48.69
4 =	64.92
5 =	81.15
6 =	97.38
7 =	113.61
8 =	129.84
9 =	146.07

<i>Cubic Centimeters</i>	<i>Fluid Ounces</i>
29.574 =	1
59.147 =	2
88.721 =	3
118.295 =	4
147.869 =	5
177.442 =	6
207.016 =	7
236.590 =	8
266.163 =	9

The U. S. gallon = 3785.44 cc; one liter = 1000 cc = 33 fluid ounces, 391 minims. It contains 231 cubic inches. A minim of water weighs 0.95 grain. A fluid ounce weighs 456 grains. The above tables also apply to the English weights and measures with the exception of the liquid measures: the British or Imperial gallon measures 160 fluid ounces = 4545.96 cc = 277.418 cubic inches (Br.) or 277.420 (U. S.). One liter = 1000 cc or ml = 35 fluid ounces, 94 minims (Br.) = 16894.1 minims. A fluid ounce of water weighs 437.5 grains and a minim is $437.5 \div 480 = 0.91$ grain. The following table must therefore be used for the conversion of the British liquid measure:

<i>Cubic Centimeters</i>	<i>Minims</i>
1 =	16.894
2 =	33.788
3 =	50.682
4 =	67.576
5 =	84.470
6 =	101.364
7 =	118.258
8 =	135.152
9 =	152.046

<i>Cubic Centimeters</i>	<i>Fluid Ounces</i>
28.4123 =	1
56.8245 =	2
85.2368 =	3
113.6490 =	4
142.0613 =	5
170.4735 =	6
198.8858 =	7
227.2980 =	8
255.7103 =	9

AREA AND VOLUME

The area of a triangle = base \times one-half of altitude.

The area of a parallelogram = base \times altitude.

The area of a trapezoid = (one-half the sum of parallel sides) \times altitude.

The area of a trapezium = combined area of the two triangles into which it may be divided.

The diagonal of a square = one side \times 1.414.

The diagonal of a rectangle = sum of squares of two adjacent sides.

The circumference of a circle = diameter \times 3.14159 or 2(radius) \times 3.14159.

The diameter of a circle = circumference \times .31831.

The area of a circle = radius squared \times 3.14159.

The area of a regular polygon = (one-half the sum of sides) \times perpendicular from center to one side.

The surface of a sphere = 4 \times radius squared \times 3.14159.

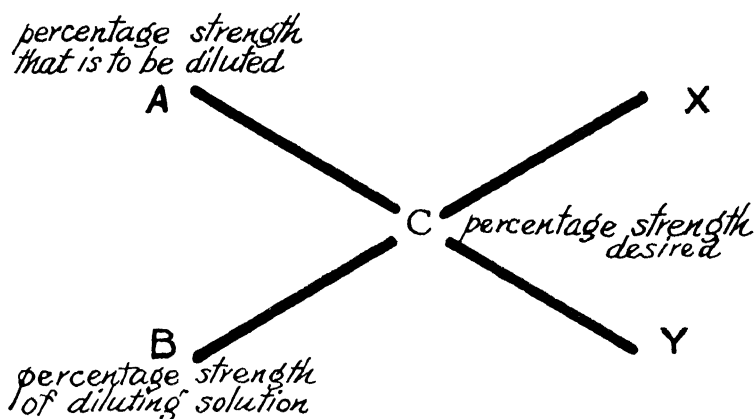
The contents of a sphere = $\frac{4}{3} \times$ radius cubed \times 3.14159.

The surface of a cylinder = area of both ends + (length \times circumference).

The contents of a cylinder = area of one end \times length.

The contents of a cone = area of base \times one-half of altitude.

CRISS-CROSS METHOD OF FIGURING PERCENTAGE SOLUTIONS. — The accompanying diagram shows a convenient method of figuring dilutions.



At A write the percentage strength of the solution that is to be diluted.

At B write the percentage strength of the diluting solution. Use 0 for water.

At C write the percentage strength desired.

Subtract C from A and write the result at Y.

Subtract B from C and write the result at X.

Then if X parts of A are diluted with Y parts of B, the result will be a solution of C percentage.

For example, if it is desired to make a 30 per cent solution of hypo from a 50 per cent stock solution, write 50 at A, 0 at B, and 30 at C. Subtracting

Hypo 50% ————— take 30 parts

30% desired

Water 0% ————— take 20 parts

30 from 50, write 20 at Y. Subtracting 0 from 30, write 30 at X. Reading the result, if 30 parts of 50 per cent hypo is diluted with 20 parts of water, the result will be a 30 per cent solution of hypo.

PERCENTAGE SOLUTIONS. — Chemicals are sometimes kept in a stock solution. Some dispute has prevailed as to the exact meaning of “ x per cent solution,” but in photographic practice it means x parts in 100 parts of the total bulk of solution. As most chemicals are sold by the avoirdupois ounce of 437.5 grains, and liquids are measured by the ounce of 480 minims, some confusion has arisen. The following tables show: (a) the accurate quantities of solids to be dissolved in sufficient liquid to make a total bulk of 100 parts for the various percentages; (b) the number of grains to be dissolved in sufficient solvent to make 1 ounce of any given percentage.

<i>Per cent</i>	<i>Grains</i>
1 =	4.375
2 =	8.75
3 =	13.125
4 =	17.50
5 =	21.875

<i>Per cent</i>	<i>Grains</i>
6 =	26.25
7 =	30.625
8 =	35.0
9 =	39.375
10 =	43.75

The number of grains of a solid which must be dissolved in sufficient liquid to make 1 fluid ounce for the various percentages:

<i>Per cent</i>	<i>Grains</i>
1 =	4.8
2 =	9.6
3 =	14.4
4 =	19.2
5 =	24.0

<i>Per cent</i>	<i>Grains</i>
6 =	28.8
7 =	33.6
8 =	38.4
9 =	43.2
10 =	48.0

These tables are sufficient to calculate any percentage or volume, by merely multiplying or adding. Example: required to make a 15 per cent solution, how many grains are required:

$$\begin{array}{r}
 10 \text{ per cent} = 43.75 \\
 5 \text{ per cent} = 21.875 \\
 \hline
 65.625 \text{ grains}
 \end{array}$$

Required 16 ounces of 10 per cent solution, how many grains required:

$$48 \times 16 = 568 \text{ grains}$$

A table listing the factors to use in making up aqueous solutions of any percentage strength, weight to volume, is published by Merck & Co. These factors are based on the value: 1 fluid ounce = 480 minims, the weight of which is 455 grains. Thus, for 10 ounces, the figure to use is 455 grains. For 16 ounces, 455×1.6 , which equals 728. For 1 ounce, 45.5 for a 10 per cent solution. For a 5 per cent solution, take one-half of the 10 per cent values, for 30 per cent, take 3×10 per cent, and so on.

SPECIFIC GRAVITY, which is the ratio of the mass of a body to the mass of an equal volume of water at 4°C. , is measured by an instrument called a *hydrometer*. In the Baumé type, which is the one most commonly used,

there are separate instruments for measuring liquids heavier than water and liquids lighter than water. Specific gravity taken by means of these hydrometers is termed in degrees Baumé (Bé.). In the system for liquids heavier than water, 0° equals a specific gravity of 1; 1° equals specific gravity 1.007; 2° equals specific gravity 1.013; 3° equals specific gravity 1.02, and so on. For liquids lighter than water, 10° equals a specific gravity of 1, and for every rise of one degree on the scale there is a drop in the specific gravity of about 0.005.

RULES FOR THE CONVERSION OF WEIGHTS AND MEASURES. —

WEIGHTS

Grains to grams: Take 6 per cent, and add 8 per cent.

Grams to grains: Multiply by 15, then increase result by 3 per cent.

Ounces to grams: Multiply by 28, then increase result by $1\frac{1}{2}$ per cent.

Grams to ounces: Take 3 per cent, and increase it by $\frac{1}{2}$ + (5 per cent of $\frac{1}{2}$).

Pounds to kilos: Take 40 per cent, and increase it by 10 per cent + ($\frac{1}{3}$ of 10 per cent).

Kilos to pounds: Multiply by 2, then increase result by 10 per cent + (2 per cent of 10 per cent).

LENGTHS

Inches to centimeters: Multiply by 2, then increase result by 25 per cent + (8 per cent of 25 per cent).

Centimeters to inches: Take 40 per cent, and diminish it by $1\frac{1}{2}$ per cent.

Yards to meters: Take 70 per cent, and increase it by 30 per cent + (2 per cent of 30 per cent).

Meters to yards: Add 9 per cent and 4 per cent of 9 per cent.

FLUID MEASURES

Pints to liters: Take 40 per cent, and increase it by 40 per cent + (5 per cent of 40 per cent).

Liters to pints: Multiply by 2, and diminish result by 12 per cent.

In all the above rules the error in no case is greater than $1/1000$.

PARTS. — Sometimes a formula is given in “parts”; it can then be read either in the metric or duodecimal system, as long as a “part” is taken as the units which may be grains, ounces, pounds, or tons, or grams or cubic centimeters.

As it is unusual to weigh liquids, the grains or pounds of water must be converted into liquid measure, hence 1000 grains = 2 fluid ounces, 137 minims.

THE THERMOMETER is an instrument for measuring temperatures. Three systems are used. Centigrade (also called Celsius) fixes 0° at the freezing point of water and 100° at its boiling point. Réaumur uses 0° for the freezing point of water and 80° for its boiling point. On the Fahrenheit scale 0° represents the temperature of equal parts of ice and salt, 32° the freezing point of water, and 212° the boiling point of water. Centigrade is used the world over, especially in scientific work. Réaumur is being gradually discarded. Fahrenheit is in common use among English-speaking people.

COMPARISON OF THERMOMETER SCALES

*Centigrade (Celsius) (C.), Réaumur (R.) and Fahrenheit (F.)*Formulas for Conversion: $t^{\circ}\text{C.} = \frac{5}{9}t^{\circ}\text{R.} = \frac{5}{9}t^{\circ}\text{F.} + 32^{\circ}\text{F.}$ $t^{\circ}\text{R.} = \frac{4}{5}t^{\circ}\text{C.} = \frac{4}{5}t^{\circ}\text{F.} + 32^{\circ}\text{F.}$ $t^{\circ}\text{F.} = \frac{9}{5}(t - 32)^{\circ}\text{C.} = \frac{9}{5}(t - 32)^{\circ}\text{R.}$

C.	R.	F.	C.	R.	F.	C.	R.	F.	C.	R.	F.
+120	+96	+248	+80	+64	+176	+40	+32	+104	±0	± 0	+32
119	95.2	246.2	79	63.2	174.2	39	31.2	102.2	-1	-0.8	30.2
118	94.4	244.4	78	62.4	172.4	38	30.4	100.4	2	1.6	28.4
117	93.6	242.6	77	61.6	170.6	37	29.6	98.6	3	2.4	26.6
116	92.8	240.8	76	60.8	168.8	36	28.8	96.8	4	3.2	24.8
115	92	239	75	60	167	35	28	95	5	4	23
114	91.2	237.2	74	59.2	165.2	34	27.2	93.2	6	4.8	21.2
113	90.4	235.4	73	58.4	163.4	33	26.4	91.4	7	5.6	19.4
112	89.6	233.6	72	57.6	161.6	32	25.6	89.6	8	6.4	17.6
111	88.8	231.8	71	56.8	159.8	31	24.8	87.8	9	7.2	15.8
110	88	230	70	56	158	30	24	86	10	8	14
109	87.2	228.2	69	55.2	156.2	29	23.2	84.2	11	8.8	12.2
108	86.4	226.4	68	54.4	154.4	28	22.4	82.4	12	9.6	10.4
107	85.6	224.6	67	53.6	152.6	27	21.6	80.6	13	10.4	8.6
106	84.8	222.8	66	52.8	150.8	26	20.8	78.8	14	11.2	6.8
105	84	221	65	52	149	25	20	77	15	12	5
104	83.2	219.2	64	51.2	147.2	24	19.2	75.2	16	12.8	3.2
103	82.4	217.4	63	50.4	145.4	23	18.4	73.4	17	13.6	1.4
102	81.6	215.6	62	49.6	143.6	22	17.6	71.6	18	14.4	- 0.4
101	80.8	213.8	61	48.8	141.8	21	16.8	69.8	19	15.2	2.2
100	80	212	60	48	140	20	16	68	20	16	4
99	79.2	210.2	59	47.2	138.2	19	15.2	66.2	21	16.8	5.8
98	78.4	208.4	58	46.4	136.4	18	14.4	64.4	22	17.6	7.6
97	77.6	206.6	57	45.6	134.6	17	13.6	62.6	23	18.4	9.4
96	76.8	204.8	56	44.8	132.8	16	12.8	60.8	24	19.2	11.2
95	76	203	55	44	131	15	12	59	25	20	13
94	75.2	201.2	54	43.2	129.2	14	11.2	57.2	26	20.8	14.8
93	74.4	199.4	53	42.4	127.4	13	10.4	55.4	27	21.6	16.6
92	73.6	197.6	52	41.6	125.6	12	9.6	53.6	28	22.4	18.4
91	72.8	195.8	51	40.8	123.8	11	8.8	51.8	29	23.2	20.2
90	72	194	50	40	122	10	8	50	30	24	22
89	71.2	192.2	49	39.2	120.2	9	7.2	48.2	31	24.8	23.8
88	70.4	190.4	48	38.4	118.4	8	6.4	46.4	32	25.6	25.6
87	69.6	188.6	47	37.6	116.6	7	5.6	44.6	33	26.4	27.4
86	68.8	186.8	46	36.8	114.8	6	4.8	42.8	34	27.2	29.2
85	68	185	45	36	113	5	4	41	35	28	31
84	67.2	183.2	44	35.2	111.2	4	3.2	39.2	36	28.8	32.8
83	66.4	181.4	43	34.4	109.4	3	2.4	37.4	37	29.6	34.6
82	65.6	179.6	42	33.6	107.6	2	1.6	35.6	38	30.4	36.4
81	64.8	177.8	41	32.8	105.8	1	0.8	33.8	39	31.2	38.2

C. P. CHEMICALS. — The term "C. P." means "chemically pure" and it refers to a chemical which has the least possible impurity content. Although this measurement varies with different manufacturers, the American Chemical Society is gradually setting standards. C. P. (or reagent) chemicals are purer than the commercial (or practical) kind and should be used whenever possible.

COINS FOR EMERGENCY WEIGHTS. — Some coins which are minted at definite legal weights may be used with scales instead of the regular weights, if they are not too much worn. The differences in the weights of the different coins may also be used, a lighter coin being placed on the same side of the scale as the material that is to be weighed. A cent, for example, weighs 50 grains, and a dime 40 grains, so by placing the dime on the scales with the material, it will be an easy matter to weigh out 10 grains. The following table gives the approximate weights of United States coins:

Dime	=	\$0.10	<i>weighs</i>	2.5 g	or	40 gr.
Cent	=	0.01		3.12 g		50 gr.
Nickel	=	0.05		5.0 g		80 gr.
Quarter	=	0.25		6.25 g		100 gr.
Half dollar	=	0.50		12.5 g		200 gr.
Dollar	=	1.00		25.0 g		400 gr.
1 Dollar and 1 nickel			<i>weigh</i>	1 oz.	apoth.	or 480 gr.
1 Half dollar and 1 dime				$\frac{1}{2}$ oz.	apoth.	240 gr.
1 Nickel and 1 dime				$\frac{1}{4}$ oz.	apoth.	120 gr.
1 Quarter minus 1 dime				1 dram	apoth.	60 gr.
1 Dollar and 1 dime				approximately 1 oz. avoirdupois		

The United States 5 cent piece is exactly 2 centimeters in diameter.

English silver coins are minted 436 grains to each 5 shillings value. A sixpenny piece is almost exactly one-tenth and a threepenny bit is one-twentieth of an ounce. A penny weighs one-third of an ounce and a half-penny one-fifth. A farthing is one-tenth of an ounce, so that 3 pennies, 5 halfpennies or 10 farthings would weigh 1 ounce. The following list gives the approximate weights of English coins:

Threepenny piece	<i>weighs</i>	20 gr.
Sixpence		40 gr.
Farthing		43 gr.
Half sovereign		61 gr.
Halfpenny		88 gr.
Sovereign		123 gr.
Penny		145 gr.
Florin (2/-)		175 gr.
Half Crown (2/6)		218 gr.
1 Halfpenny and 1 threepenny piece	<i>weigh</i>	$\frac{1}{4}$ oz.
1 Florin and sixpence		$\frac{1}{2}$ oz.
3 Pennies or 5 halfpennies		1 oz.
48 Pennies		1 lb.

French coins are particularly suitable for use as metric weights. They are as follows:

5 Francs (silver)	<i>weigh</i>	25 g	10 Centimes (bronze)	<i>weigh</i>	10 g
2 Francs	"	10 g	5 Centimes	"	5 g
1 Franc	"	5 g	2 Centimes	"	2 g
$\frac{1}{2}$ Franc	"	$2\frac{1}{2}$ g	1 Centime	"	1 g

CHAPTER XXV

CHEMICAL TABLES

TABLE OF SYMBOLS AND APPROXIMATE MOLECULAR WEIGHTS OF THE MORE IMPORTANT COMPOUNDS USED IN PHOTOGRAPHY

The numbers in parentheses after the chemical symbols indicate the position on the benzene nucleus.

Name	Symbol	Mol. Weight
Acetone	CH_3COCH_3	58
— sulphite	$\text{C}_6\text{H}_5\text{OHSO}_3\text{Na}$	162
Acid, acetic	CH_3COOH	60
— benzoic	$\text{C}_6\text{H}_5\text{COOH}$	122
— boric	H_3BO_3	62
— carbolic	$\text{C}_6\text{H}_5\text{OH}$	94
— chromic (anhydride)	CrO_3	100
— citric	$(\text{COOH})\text{CH}_2\text{C}(\text{OH})(\text{COOH})\text{CH}_2\text{COOH}$	192
— formic	HCOOH	46
— gallic	$(\text{HO})_3\text{C}_6\text{H}_2\text{COOH}$	170
— hydrobromic	HBr	80
— hydrochloric	HCl	36.5
— hydrofluoric	HF	20
— lactic	$\text{CH}_3\text{CHOHCOOH}$	90
— nitric	HNO_3	63
— oxalic	$\text{COOHCOOH} \cdot 2\text{H}_2\text{O}$	126
— phosphoric	H_3PO_4	98
— picric	$(\text{NO}_2)_3\text{C}_6\text{H}_2\text{OH}$	229
— pyrogallic	$\text{C}_6\text{H}_3(\text{OH})_3$	126
— salicylic	$\text{HOC}_6\text{H}_4\text{COOH}$	138
— sulphuric	H_2SO_4	98
— sulphurous	H_2SO_3	82
— tannic	$\text{C}_{14}\text{H}_{10}\text{O}_9$	322
— tartaric	$(\text{COOH})\text{C}(\text{OH})_2\text{C}(\text{OH})_2\text{COOH}$	182
Alcohol (methyl)	CH_3OH	32
(ethyl)	$\text{CH}_3\text{CH}_2\text{OH}$	46
Alum, ammonia	$\text{NH}_4\text{Al}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$	453
— chrome	$\text{Cr}_2\text{K}_2(\text{SO}_4)_4 \cdot 24\text{H}_2\text{O}$	998
— iron ammonia	$\text{Fe}_2(\text{NH}_4)_2(\text{SO}_4)_4 \cdot 24\text{H}_2\text{O}$	964
— potash	$\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$	474
Aluminum chloride	$\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$	241
— sulphate	$\text{Al}_2(\text{SO}_4)_3 \cdot \text{H}_2\text{O}$	504
Amidol (Diaminophenol)	$(\text{NH}_2)_2\text{C}_6\text{H}_3\text{OH} \cdot 2\text{HCl}(1,2,4)$	197
Ammonia	NH_3	17
Ammonium bichromate	$(\text{NH}_4)_2\text{Cr}_2\text{O}_7$	252
— bromide	NH_4Br	98
— carbonate	$(\text{NH}_4)_2\text{CO}_3 \cdot \text{H}_2\text{O}$	114
— chloride	NH_4Cl	53.5

<i>Name</i>	<i>Symbol</i>	<i>Mol. Weight</i>
Ammonium chromate	$(\text{NH}_4)_2\text{CrO}_4$	152
— citrate	$(\text{NH}_4)_3\text{HC}_6\text{H}_5\text{O}_7$	226
— iodide	NH_4I	145
— molybdate	$(\text{NH}_4)_2\text{MoO}_4$	196
— nitrate	NH_4NO_3	80
— oxalate	$(\text{NH}_4)_2\text{C}_2\text{O}_4\text{H}_2\text{O}$	142
— persulphate	$(\text{NH}_4)_2\text{S}_2\text{O}_8$	228
— phosphate	$(\text{NH}_4)_2\text{HPO}_4$	132
— sulphate	$(\text{NH}_4)_2\text{SO}_4$	132
— sulphide	NH_4HS	51
— sulphocyanide	NH_4SCN	76
— vanadate	NH_4VO_3	117
Amyl, acetate	$\text{C}_5\text{H}_{11}\text{O}_2$	130
— alcohol	$\text{CH}_3\text{CH}_2\text{C}(\text{CH}_3)\text{OHCH}_3$	88
Aniline	$\text{C}_6\text{H}_5\text{NH}_2$	93
Antimony, sulphide	Sb_2S_3	339.7
Aurantia	$(\text{C}_6\text{H}_3(\text{NO}_2)_2)_2\text{NNH}_4$	456
Aurine	$\text{C}_{10}\text{H}_{14}\text{O}_8$	290
Barium, bromide	BaBr_2	297
— chloride	BaCl_2	208
— iodide	$\text{BaI}_2 \cdot 2\text{H}_2\text{O}$	427
— nitrate	$\text{Ba}(\text{NO}_3)_2$	261
— peroxide	BaO_2	169
— sulphate	BaSO_4	233
Benzene (benzol)	C_6H_6	78
Borax (see Sodium Borate)		
Bromine	Br_2	160
Cadmium, bromide	CdBr_2	272
— chloride	CdCl_2	183
— iodide	CdI_2	366
Calcium, carbide	CaC_2	64
— carbonate	CaCO_3	100
— chloride (cryst.)	$\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$	219
— — (fused)	CaCl_2	111
— hypochlorite	$\text{Ca}(\text{ClO})_2$	153
— sulphate	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	172
— hydroxide (slaked lime)	$\text{Ca}(\text{OH})_2$	74
Carbon, bisulphide	CS_2	76
Celloidin	$\text{C}_{12}\text{H}_{18}\text{O}_6(\text{NO}_2)_4$	504
Ceric, sulphate	$\text{Ce}(\text{SO}_4)_3 \cdot 4\text{H}_2\text{O}$	640.5
Chloral hydrate	$\text{CCl}_3\text{CH}(\text{OH})_2$	165.5
Chloroform	CHCl_3	119.5
Chrysoidine	$\text{C}_6\text{H}_5\text{N}:\text{NC}_6\text{H}_3(\text{NH}_2)_2$	212
Cobalt, chloride	$\text{CoCl}_2 \cdot 2\text{NH}_3$	164
Copper, bromide	CuBr_2	223.5
— chloride	$\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$	170.5
— nitrate	$\text{Cu}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	296
— sulphate	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	249.7
Cyanine	$\text{C}_{20}\text{H}_{15}\text{N}_3\text{I}$	544
Dextrin	$(\text{C}_6\text{H}_{10}\text{O}_5)_x$	162
Diaminophenol	$(\text{NH}_2)_2\text{C}_6\text{H}_3\text{OH}$	124

<i>Name</i>	<i>Symbol</i>	<i>Mol. Weight</i>
Elon	$C_6H_4(OH)(NHCH_3) \cdot \frac{1}{2}H_2SO_4(1,4)$	344
Eosin	$C_{20}H_8Br_4Na_2O_8$	691.7
Erythrosin	$C_{20}H_8I_4O_8$	836
Ether	$C_2H_5OC_2H_5$	74
Ferrous and ferric salts (see Iron)		
Formaldehyde	HCHO	30
Formaline	40 per cent sol. of HCHO	—
Glycerin (Glycerol)	$CH_2OHCHOHCH_2OH$	92
Glycin	$C_6H_5OHNHCH_2COOH$	167
Gold, chloride brown	$AuCl_3$	304
— — potassium	$KAuCl_4 \cdot 2H_2O$	414
— — sodium	$NaAuCl_4 \cdot 2H_2O$	398
— — yellow	$AuCl_3 \cdot 2H_2O$	340
Hydrogen, peroxide	H_2O_2	34
Hydroquinone	$C_6H_4(OH)_2(1,4)$	110
Iodine	I_2	253
Iron.		
Ferric chloride (dry)	$FeCl_3$	127
— — (lump)	$FeCl_3 \cdot 4H_2O$	199
— ammonium citrate, brown	$4FeC_6H_5O_7 \cdot 3(NH_4)_3C_6H_5O_7 \cdot 3Fe(OH)_3$	2030
— — — green	$5FeC_6H_5O_7 \cdot 2(NH_4)_3C_6H_5O_7 \cdot NH_4C_6H_7O_7 \cdot 2H_2O$	1956
— oxalate	$Fe_2(C_2O_4)_3$	376
— ammonium oxalate	$(NH_4)_3Fe(C_2O_4)_2 \cdot 2H_2O$	—
— potassium oxalate	$K_3Fe(C_2O_4)_3 \cdot 3H_2O$	491
— sodium oxalate	$Na_3Fe(C_2O_4)_3 \cdot 5H_2O$	479
Ferrous, chloride (dry)	$FeCl_2$	127
— — (cryst.)	$FeCl_2 \cdot 4H_2O$	199
— oxalate	$FeC_2O_4 \cdot 2H_2O$	180
— potassium oxalate	$K_2Fe(C_2O_4)_2 \cdot 2H_2O$	346
— sulphate	$FeSO_4 \cdot 7H_2O$	278
— ammonium sulphate	$(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$	392
Lead, acetate	$Pb(C_2H_3O_2)_2 \cdot 3H_2O$	379
— nitrate	$Pb(NO_3)_2$	331
Lithia, caustic	$LiOH$	24
Lithium, bromide	$LiBr$	87
— carbonate	Li_2CO_3	74
— chloride	$LiCl$ (cryst. has $2H_2O$)	42.5
— iodide	LiI	134
Magnesium, chloride	$MgCl_2$	95
— sulphate	$MgSO_4$	120
Manganese, dioxide	MnO_2	87
— sulphate	$MnSO_4$	151
Mercury	Hg	200
— bichloride	$HgCl_2$	271
— iodide	HgI_2	454
— potassium iodide (soluble)	$KI \cdot HgI_2$	620
Metol *	$(CH_3NHC_6H_4OH)_2 \cdot H_2SO_4(1,4)$	344

* Metol is the sulphate of mono-methyl-para-amino-phenol.

<i>Name</i>	<i>Symbol</i>	<i>Mol. Weight</i>
Palladious chloride	PdCl_2	177
— potassium chloride	K_2PdCl_4	326
Para-aminophenol (Rodinal)	$\text{NH}_2\text{C}_6\text{H}_4\text{OH}$	109
Phenol (see Acid, carbohic)		
Platinum per- (or bi-) chloride	$\text{H}_2\text{PtCl}_6\text{H}_2\text{O}$	516.4
Potassium, ammonium chromate	KNH_4CrO_4	173
— bicarbonate	KHCO_3	100
— bichromate	$\text{K}_2\text{Cr}_2\text{O}_7$	294
— boro-tartrate	$\text{KC}_4\text{H}_4\text{BO}_7$	214
— bromide	KBr	119
— carbonate (dry)	K_2CO_3	138
— chlorate	KClO_3	122.5
— chloride	KCl	74.5
— chloro-platinite	K_2PtCl_4	415
— chromate	K_2CrO_4	194
— citrate	$\text{K}_3\text{C}_6\text{H}_5\text{O}_7\text{H}_2\text{O}$	342
— cyanide	KCN	65
— ferricyanide	$\text{K}_3\text{Fe}(\text{CN})_6$	329
— ferrocyanide	$\text{K}_4\text{Fe}(\text{CN})_6\text{H}_2\text{O}$	422
— hydroxide	KOH	56
— iodide	KI	166
— metabisulphite	$\text{K}_2\text{S}_2\text{O}_5$	222
— nitrate	KNO_3	101
— nitrite	KNO_2	85
— oxalate	$\text{K}_2\text{C}_2\text{O}_4\text{H}_2\text{O}$	184
— percarbonate	$\text{K}_2\text{C}_2\text{O}_6$	198
— perchlorate	KClO_4	138.5
— permanganate	KMnO_4	158
— persulphate	$\text{K}_2\text{S}_2\text{O}_8$	270
— sulphate	K_2SO_4	174
— sulphocyanide	KSCN	97
Pyrocatechin	$\text{C}_6\text{H}_4(\text{OH})_2(1,2)$	110
 Rochelle salt	 $\text{KNaC}_4\text{H}_4\text{O}_6\text{H}_2\text{O}$	 282
 Schlippe's salt (sodium sulphantimoniate)	 $\text{Na}_3\text{SbS}_4\text{H}_2\text{O}$	 481
Silver, acetate	$\text{AgC}_2\text{H}_3\text{O}_2$	167
— ammonium nitrate	$\text{AgNO}_3 + 2\text{NH}_3$	204
— bromide	AgBr	188
— carbonate	Ag_2CO_3	276
— chloride	AgCl	143.3
— citrate	$\text{Ag}_3\text{C}_6\text{H}_5\text{O}_7$	513
— fluoride	AgF	127
— iodide	AgI	235
— nitrate	AgNO_3	170
— nitrite	AgNO_2	154
— oxalate	$\text{Ag}_2\text{C}_2\text{O}_4$	304
— oxide	Ag_2O	232
— phosphate (ortho)	Ag_3PO_4	419
— sulphate	Ag_2SO_4	312
— sulphide	Ag_2S	248
— tartrate	$\text{Ag}_2\text{C}_4\text{H}_4\text{O}_6$	364

<i>Name</i>	<i>Symbol</i>	<i>Mol. Weight</i>
Sodium, acetate	$\text{NaC}_2\text{H}_3\text{O}_2 \cdot 3\text{H}_2\text{O}$	136
— — (fused)	$\text{NaC}_2\text{H}_3\text{O}_2$	82
— bicarbonate	NaHCO_3	84
— bichromate	$\text{Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$	298
— bisulphite	NaHSO_3	104
— borate	$\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$	381.5
— bromide	$\text{NaBr} \cdot 2\text{H}_2\text{O}$	139
— carbonate (anhydrous)	Na_2CO_3	106
— — (cryst.)	$\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$	286
— chloride	NaCl	58.5
— chloro-platinite	$\text{Na}_2\text{P} + \text{Cl}_4 \cdot 4\text{H}_2\text{O}$	455
— citrate	$\text{Na}_3\text{C}_6\text{H}_5\text{O}_7 \cdot 5\text{H}_2\text{O}$	348
— fluoride	NaF	42
— hydroxide (caustic)	NaOH	40
— iodide	NaI	150
— nitrate	NaNO_3	85
— nitro-prusside	$\text{Na}_2(\text{NO})\text{Fe}(\text{CN})_5 \cdot 2\text{H}_2\text{O}$	298
— oxalate	$\text{Na}_2\text{C}_2\text{O}_4$	134
— phosphate	$\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$	358
— tribasic phosphate	$\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$	380
— sulphate (cryst.)	$\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$	322
— sulphide	$\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$	240
— sulphite (anhydrous)	Na_2SO_3	126
— — (cryst.)	$\text{Na}_2\text{SO}_3 \cdot 7\text{H}_2\text{O}$	252
— thiosulphate (hypo)	$\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$	248
— tungstate	Na_2WO_4	294
Strontium, bromide	SrBr_2	247.5
— chloride (dry)	SrCl_2	158.5
— — (cryst.)	$\text{SrCl}_2 \cdot 2\text{H}_2\text{O}$	194.5
— iodide	SrI_2	341.5
— nitrate	$\text{Sr}(\text{NO}_3)_2$	211.6
Thiocarbamide (thiourea)	NH_2CSNH_2	76
Thiosinamine	$\text{CH}_2\text{:CHCH}_2\text{NHCSNH}_2$	116
Thymol	$\text{CH}_3(\text{C}_6\text{H}_7)\text{C}_6\text{H}_5\text{OH}$	150
Tin (stannous) chloride	$\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$	225.6
Uranium, acetate	$\text{UO}_2(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 2\text{H}_2\text{O}$	424
— chloride	UO_2Cl_2	341
— nitrate	$\text{UO}_2(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	502
Zinc, sulphate	$\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$	287.5

A TABLE OF ATOMIC WEIGHTS OF THE ELEMENTS

<i>Name</i>	<i>Symbol</i>	<i>Atomic Weight in Round Numbers</i>	<i>Accurate Atomic Weight</i>
Actinium	Ac	227 (approx.)	—
Alabamine	Ab	221	221.000
Aluminum	Al	27	26.970
Antimony	Sb	121	121.760
Argon	A	40	39.944
Arsenic	As	75	74.910

<i>Name</i>	<i>Symbol</i>	<i>Atomic Weight in Round Numbers</i>	<i>Accurate Atomic Weight</i>
Barium	Ba	137	137.360
Beryllium (Glucinum)	Be = Gl	9	9.020
Bismuth	Bi	209	209.000
Boron	B	11	10.820
Bromine	Br	80	79.916
Cadmium	Cd	112	112.410
Calcium	Ca	40	40.080
Carbon	C	12	12.010
Cerium	Ce	140	140.130
Cesium	Cs	133	132.910
Chlorine	Cl	35.5	35.457
Chromium	Cr	52	52.010
Cobalt	Co	59	58.940
Columbium (Niobium)	Cb = Nb	93	92.910
Copper	Cu	63.6	63.570
Dysprosium	Dy	162.5	162.460
Erbium	Er	167	167.200
Fluorine	F	19	19.000
Gadolinium	Gd	157	156.900
Gallium	Ga	70	69.720
Germanium	Ge	72.6	72.600
Gold	Au	197	197.200
Hafnium	Hf	178.6	178.600
Helium	He	4	4.003
Holmium	Ho	163.5	163.500
Hydrogen	H	1	1.008
Illinium	Il	146 (est.)	—
Indium	In	115	114.760
Iodine	I	127	126.920
Iridium	Ir	193	193.100
Iron	Fe	56	55.840
Krypton	Kr	83.7	83.700
Lanthanum	La	139	138.920
Lead	Pb	207	207.210
Lithium	Li	7	6.940
Lutecium	Lu	175	175.000
Magnesium	Mg	24	24.320
Manganese	Mn	55	54.930
Masurium	Ma	—	—
Mercury	Hg	200	200.610
Molybdenum	Mo	96	95.950

<i>Name</i>	<i>Symbol</i>	<i>Atomic Weight in Round Numbers</i>	<i>Accurate Atomic Weight</i>
Neodymium	Nd	144	144.270
Neon	Ne	20	20.183
Nickel	Ni	59	58.690
Nitrogen	N	14	14.008
Osmium	Os	190	190.200
Oxygen	O	16	16.000
Palladium	Pd	107	106.700
Phosphorus	P	31	31.020
Platinum	Pt	195	195.230
Polonium	Po	210 (approx.)	—
Potassium	K	39	39.096
Praseodymium	Pr	141	140.920
Protoactinium	Pa	231	231.000
Radium	Ra	226	226.050
Radon (Niton)	Rn	222	222.000
Rhenium	Re	186	186.310
Rhodium	Rh	103	102.910
Rubidium	Rb	85.5	85.480
Ruthenium	Ru	102	101.700
Samarium	Sm	150	150.430
Scandium	Sc	45	45.100
Selenium	Se	79	78.960
Silicon	Si	28	28.060
Silver	Ag	108	107.880
Sodium	Na	23	22.997
Strontium	Sr	87.6	87.630
Sulphur	S	32	32.060
Tantalum	Ta	181	180.880
Tellurium	Te	128	127.610
Terbium	Tb	159	159.200
Thallium	Tl	204	204.390
Thorium	Th	232	232.120
Thulium	Tm	169.4	169.400
Tin	Sn	119	118.700
Titanium	Ti	48	47.900
Tungsten	W	184	183.920
Uranium	U	238	238.070
Vanadium	V	51	50.950
Virginium	Vi	224 (about)	—
Xenon	Xe	131.3	131.300
Ytterbium	Yb	173	173.040
Yttrium	Y	89	88.920
Zinc	Zn	65.4	65.380
Zirconium	Zr	91	91.220

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